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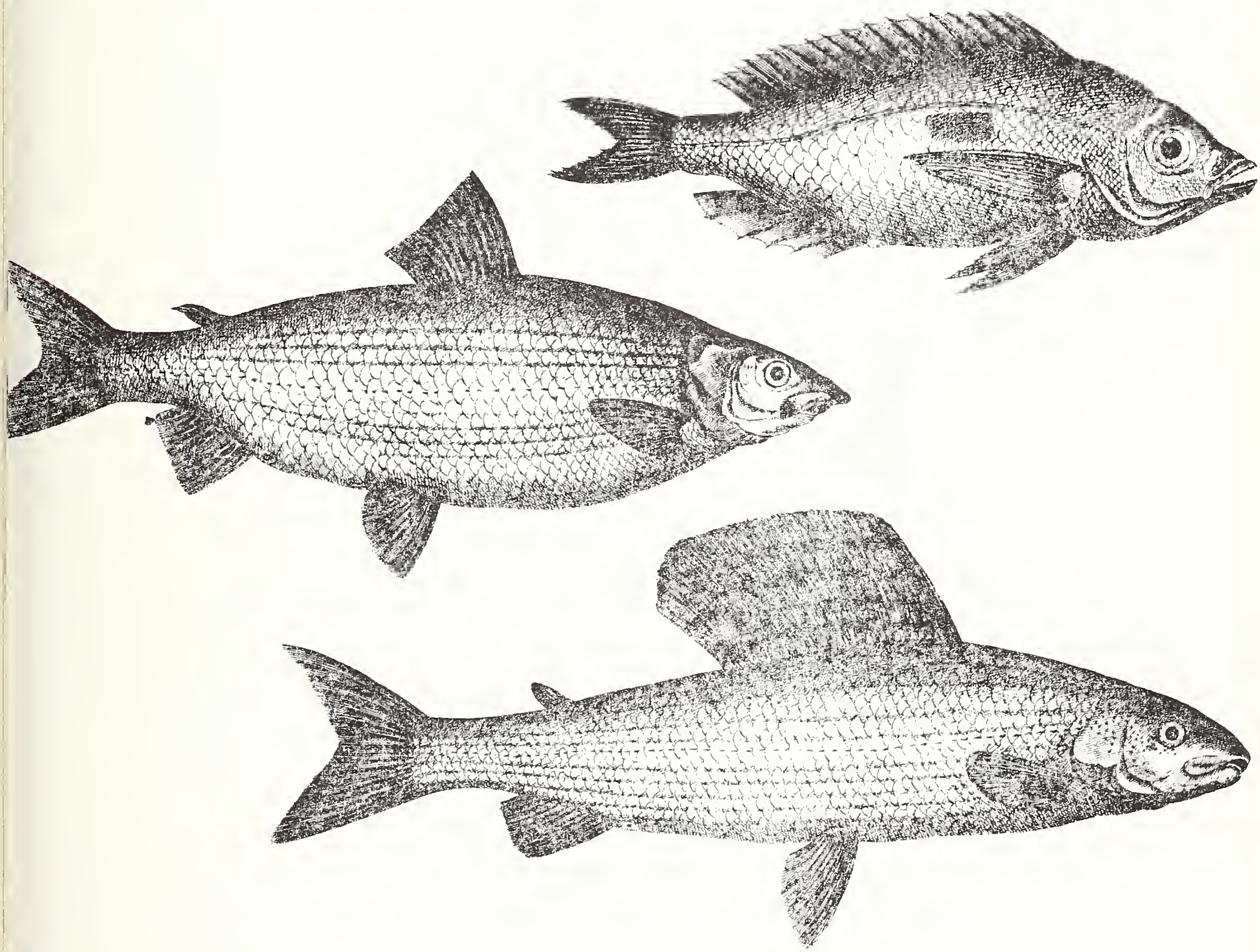

AQUACULTURE AND THE AMERICAN FOOD SUPPLY

The Associates of the National Agricultural
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Cover Photo: *From top to bottom, "La Mandole," "Le Large," and "L'Ombre de Riviere" as found in Bonnaterre's* Tableau Encyclopédique et Méthodique, *1768; Courtesy, National Agricultural Library, Rare Book Collection.*

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CONTNETS

FOREWORD

For centuries, people have been experimenting with the possibility of propagating and raising aquatic animals and plants in a controlled environment. Today's growing international food needs have accentuated the potential for aquaculture as a source of nutritious food. Countries such as China, Japan, and the Soviet Union have been expanding their aquacultural activities. In the United States, where aquaculture accounts for only eight percent of its total seafood supply, growing interest, activities, and support recently have been demonstrated officially with the Congressional passage of the National Aquaculture Act of 1980 (P.L.96-342). This legislation affirms the Federal Government's recognition of the importance of aquaculture and the need for effective related programs.

Today, the National Agricultural Library, with its specialized holdings and access capabilities to various computerized data bases such as AGRICOLA (AGRICultural On-Line Access), Aquaculture, ASFA (Aquatic Sciences and Fisheries Abstracts), Aqualine, and Biosis, is a major source of information on world-wide aquacultural activities.

I compliment the editorial staff of the Associates of NAL for developing this special issue.

Richard A. Farley
Acting Director, National
Agricultural Library

("Le Picarel" as found in Bonnaterre's Tableau Encyclopédique et Méthodique . . . Ichthyologie, *1788; Courtesy, National Agricultural Library, Rare Book Collection)*

AQUACULTURE OUTLOOK

By

JOHN H. GREEN*

I. INTRODUCTION

Aquaculture is the art of regulating either freshwater or marine water environments for the cultivation of plants and animals useful to mankind; the art is rapidly becoming a science. The production of fish by aquacultural methods can efficiently provide protein food for humans, feed for animals, or other benefits such as aquatic weed control by herbivorous fish and ornamental fish for human enjoyment. The production of aquatic plants by aquacultural methods can provide food for humans, feed and fodder for animals, wastewater treatment systems for municipal and industrial wastes, biomass for fuel, chemicals for industry, and other benefits.

Aquaculture has been practiced by mankind for at least four millennia or longer. Agriculture, which has been practiced for about 12 millennia or longer, is far more technologically advanced. Aquaculture is currently an important supply of protein food in the Orient. As the need for protein food increases, however, food scientists in all parts of the world recognize the importance of aquaculture as an efficient means of food production. Technological advances are are being made to improve aquaculture production. The United States both has an increasing production of aquacultural products and is taking an active lead in developing technology to improve production.

HISTORY OF AQUACULTURE

Aquaculture is an ancient art dating back in recorded history to about 2000 B.C. when an Egyptian tomb frieze had scenes depicting what appears to be pond rearing of tilapia, a herbivorous fish which easily adapts to pond rearing in warmer climates. Asian books and records, from about 1243 B.C. on, have described various aspects of aquaculture. In about 1135 B.C., the writings of Wen Fang, founder of the Chou Dynasty, China described pond rearing of fish. Greeks and Romans, before the time of Christ, cultivated fish in ponds; the Romans also cultivated oysters. Tilapia and other pond cultivated fish were common in the Near East at the time of Christ. Recorded information, methods of cultivation, and laws governing aquaculture have been written in many parts of the world since the time of Christ.

The methods of aquaculture range from enhancing the survival of desired plants or animals in the natural environment, such as rearing oyster spats (young oysters) and seeding them into the Long Island or Chesapeake Bay oyster beds, to modern closed-loop aquaculture systems complete with environmental controls and automatic feeding systems. In between are various pond systems with various developed stages of environmental controls, feeding systems, and harvesting methods.

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THE MERITS OF AQUACULTURE

1. The main objective is to increase world food production through aquaculture. Until recently, few technological advances were made in aquaculture. The possibilities of expanding food production through aquaculture by technological improvements seem unlimited. Agriculture through technological advances has reached its zenith. There are new technological advances on the horizon, such as genetic engineering, but the possibilities for expanding food production through agriculture seem limited; for one reason, the amount of available prime farmland is declining. Most aquaculture systems do not need prime farmland.

2. Aquaculture can be developed to utilize three dimensions of its allotted space. This is called polyculture; several species of fish and one or more plants can be grown in the same pond thus utilizing every niche of available space.

3. Aquaculture yields protein crops in less area than the equivalent production of protein by agricultural methods. Aquatic animals are usually more efficient converters of protein from primary foods. Agriculture utilizes more area to grow primary foods, usually cereals, and then additional land (or space) to raise animals for protein food.

4. Aquaculture is less severely affected by weather or changes in climate than agriculture. Aquaculture can also be adapted to arid or tropical climates which are often not favorable for production of livestock.

5. Aquaculture can employ marine or brackish waters for the production of foods. These waters cannot normally be used by agriculture.

6. Aquaculture has several advantages over the capture (traditional) fisheries which will be discussed in more detail below. It is predicted that aquaculture will eventually replace capture fisheries as the main method of supply of aquatic plants and animals.

7. Aquaculture is a less energy intense method of producing food than modern agricultural practices and catch fishery methods.

As technological advances are made in aquaculture, however, energy consumption undoubtedly will increase as labor intensity decreases and production efficiency increases.

II. AQUACULTURE COMPARED TO AGRICULTURE

Prehistoric humans depended upon wild plants and animals or fish for their food supply. About 12,000 years ago, humans began to cultivate food crops and herd animals, the first stages of agriculture. During most of these 12,000 years, the science and technology of agriculture slowly progressed until the latter half of the 19th century. Then the emerging new sciences and technologies of the Western world were applied to agriculture and agricultural technology was crescendoed rapidly to the present state-of-the-art. Such basic sciences such as chemistry, biology, physics, genetics, and nutrition coupled with applied technologies such as agronomy and agricultural engineering have enabled humans to efficiently increase their food supply.

The Morrill Act of 1862 which established Land Grant Colleges was a great impetus in fostering the advancement of American agricultural technology. It should be mentioned that the Morrill Act of 1862 did not include fisheries and, as a result, the American fishing industry failed to reap the benefits of advancing technology. The National Sea Grant College and Program Act of 1966 was passed to make up this deficiency. It has begun to have impact on many phases of the fishing industry including aquaculture.

On a world-wide basis aquaculture, which has been practiced for about 4,000 years, has reached a high state-of-the-art from a cultural point of view in Asia and some other parts of the world. Modern technological advances, however, only recently have been applied to aquaculture. Japan, China, Russia and, to some extent, India have made technological

advances in aquaculture. The United States, which did not have much aquaculture a few decades ago, is making rapid advances in certain areas such as catfish farming and shellfish culture.

In terms of food supply for increasing populations, the problems faced by agriculture are limited (actually decreasing) prime land for agriculture, limited water availability, increased costs for energy sources, and possible climatic changes in many parts of the world within the coming century and beyond. Meanwhile, the technological advances for food production efficiency in agriculture are beginning to level off. More agricultural food production efficiency can be achieved by expenditures of more energy and more efficient use of our water supply (e.g. recycling wastewater or drip irrigation methods). New scientific technologies such as genetic engineering will emerge from time to time to help increase our agricultural food supply. Most authorities, however, express doubt that advances in agricultural technology can keep pace with increasing populations.

Aquacultural technology in most parts of the world today is about where agricultural technology was in the latter part of the 19th century. Until recent years very little modern scientific technology has been applied to aquaculture. In many parts of the world the state-of-the-art for aquaculture has achieved a very high degree of skills based on many centuries, if not millennia, of knowledge gained through experience. If the application of modern scientific technology can achieve for aquaculture in the next few decades what it did for agriculture during the last 100 years, then aquaculture could very well become a major supplier of food for increasing populations. The major advantages of aquaculture for food production have already been listed in the section above. Some of the technological needs for aquaculture are given below under section IV.

III. AQUACULTURE VERSUS CATCH-TYPE FISHERIES

The traditional catch-type fisheries employing harpoons, traps, hook and line, nets, or other gear have been used by humans for several millennia to supply food. This food supply is dependent upon the natural ecology to maintain populations of aquatic animals suitable for human consumption. It is analogous to hunting wild animals on land--a major source of protein food in more primitive societies. As the technology for harvesting fish (or other aquatic biota) increases, there is danger of overfishing thus upsetting the ecology of aquatic populations and perhaps permanently losing a desired food supply. The decline of sardine fishing off the California Coast in the first part of the 20th century is one such example of overfishing; so far the sardine population has not returned.

Since the beginning of the 20th century, the Federal Government of the United States, some state governments like Maine and Alaska, and governments of other countries have established fishery management programs. These fishery management programs, similar to wildlife management programs, attempt to maintain stable fish populations of desired commercial fish by regulating fishing operations. They do this by setting annual quotas and fishing seasons for each species of fish, specifying minimum mesh sizes for nets, regulating other attributes of fishing gear, and taking other measures to assure that the species will be maintained and not overfished. An example of overfishing in the 1960's was the Russian vessels in our North Atlantic which used oversized nets with smaller mesh sizes. They also fished during off seasons or in protected areas. The Russians depleted the populations of haddock and other desired commercial species.

One of the major marketing problems of catch-type fisheries is that they cannot guarantee the steady supply and uniform quality of a given product. From the above we see that fishing seasons and annual yields may vary and, from time to time, stocks of commercial fish are depleted. In reality, the fisherman does not know what he has for market until the nets come up. Then the vessel captain often communicates by radio with the fish broker, a very important market link, who in turn must sell a vessel load of fish while the vessel is returning to port.

Aquaculture does not solve all problems for the fisheries but aquaculture has certain advantages over catch-type fisheries. For those species of animal (or plant) which can be adapted to aquaculture, the following advantages can be realized: the supply can be maintained at a rate to satisfy demand; the quality of supply such as uniform size, age, and physiological health can be controlled; many capital, labor, and energy expenditures associated with fishing operations can be reduced or eliminated; the rearing environment can be controlled (temperature, aeration, food supply, etc.) for optimum growth despite changing climatic conditions and, once nutritional requirements, genetic breeding, and other scientific phenomena are understood, aquatic animals or plants could be raised very efficiently to supply human needs.

IV. METHODS OF AQUACULTURE

Methods of aquaculture are quite varied and exist in a wide range from simple enrichment techniques to sophisticated systems. The aquatic requirements range between fresh water to marine (saline) water with estuarine (various degrees of salinity) waters in between. Some estuarine animals like crabs require varying degrees of salinity at various stages which reflect the environmental changes that occur during their natural life cycle. Other environmental factors such as temperature and aeration are often critical for the survival, growth, and spawning of the species; some tropical fish will die if the water temperature drops below critical temperatures that would be considered only cool or cold.

Feeding of aquatic animals in aquacultural systems ranges from using natural food in the water or on the bottom to adding artificial food formulated to the dietary requirements of the species. In between this range are variations such as enrichment of the rearing water to enhance the production of natural food such as algae or the addition of artificial food to supplement the natural diet. Some animals raised in aquacultural systems are piscivorous and require either the addition of live fish to the pond or the co-rearing of fish in the same pond for their food supply.

Spawning and genetic breeding are two of the important areas that will need research and development if aquaculture is to advance technologically. Many aquatic animals do not spawn in captivity. Fertile eggs or young fry must be captured in the natural environment and placed in ponds for rearing. Some species do spawn in captivity. Mechanisms have been found, such as injection of pituitary hormones (extracts, etc.) or massaging adult females, which induce spawning in aquatic animals which did not spawn in captivity before. Genetic control to improve aquatic species is an important area that is still in its infancy. Research in this latter area could do much to advance aquaculture.

Aquacultural methods are on the horizon of being advanced by the application of modern science and technology. Research into nutrition, genetic breeding, and proper environmental conditions for optimum growth will greatly improve the efficiency of aquaculture as a means of supplying food and other necessities for humans.

V. SOME ASPECTS OF AQUACULTURE IN THE UNITED STATES

The United States, which had very little history of aquacultural activities and very little aquaculture production compared, for example, to Asia, has emerged in the last few decades as a leader of technological developments in aquaculture. Aquacultural production in the United States for food supply still has a low profile, compared to agricultural animal production but advances are being made in such areas as freshwater culture, mariculture, ocean ranching, and the use of aquatic plants and animals in waste-water treatment.

FRESHWATER:

Channel catfish is the principal freshwater fish cultured in the United States. It requires warm water and, therefore, is grown primarily in southeastern states, Texas, and southern California. Some more northern Mid-West states like Illinois and Indiana, which have warm summers, have engaged in catfish farming using controlled temperature ponds to maintain spawning adults and fry (young) during colder months.

The aquacultural production of rainbow trout is a relatively large industry in several northern states, especially in Idaho. Rainbow trout require cool water and the Snake River in Idaho maintains a constant ideal temperature (14-15°C) for rainbow trout. Although many aquacultural reared rainbow trout are harvested, dressed, frozen, and packaged for retail and restaurant trade, many trout are transported to fee fish-out operations. There are about 2,000 commercial fee fish-out facilities in the United States which cater to sports fishers and others. In addition, there are an estimated 150,000 privately owned sports fish ponds many of which stock the ponds with aquacultural raised fry or young adults.

Some other freshwater fish are reared in aquaculture systems in the United States. One of these is the big mouth buffalo fish which is raised in warmer climates and, so far, has a limited market in southern states. Tilapia is also raised in the South; it is an important food fish in many parts of the world. Tilapia's market as a food fish is limited in the United States but its herbivorous feeding habits make it important for removing aquatic weeds from waterways and rivers in the South.

In Louisiana, crayfish (sometimes called crawfish) are raised in rice paddies during the off season for rice crops. The crayfish eat the rice stubble and other aquatic vegetation (e.g. weeds) on the bottom of the pond thus providing a second crop as well as a service to the rice farmers. Crayfish are a popular food item in the French cultural heritage of Louisiana.

Other types of freshwater aquacultural crops in the United States are ornamental fish and bait fish. A fairly large aquaculture industry exists in producing goldfish and a variety of tropical fish for the ornamental fish trade. Bait fish farming is becoming an important industry in some areas. It is often cheaper to raise bait fish in ponds then to go out in fishing boats to harvest fish for bait which had been the traditional way when labor and energy were less costly.

MARICULTURE:

Mariculture takes a variety of forms in both estuarine and ocean waters. The natural oyster beds in the Chesapeake Bay and off of Long Island are seeded with oyster spats (young oysters) raised in aquaculture systems. This enrichment of natural oyster beds assures continual high yields; in the natural environment, the vast majority of oyster eggs and larvae are lost to predators before they reach the spat stage.

Research is being done by the National Marine Fisheries Service (U.S. Department of Commerce) and Sea Grant Programs at many state universities on the culture of crustacean and mollusk species. Many shrimp farms exist in southern states. Lobster and crab cultures are still in the experimental stages. Clams, oysters, mussels, abalone, scallops, and other mollusks are also in the experimental stage but some species of clams and oysters will probably soon become commercial ventures; abalones are now raised in Japan.

The culture of salmon takes two forms. Some salmon are being reared to market size in cages set out in the ocean. Large numbers of salmon eggs, however, are reared to young fingerling size. These are set free to roam the ocean and return as mature adults to supply our fisheries. This latter aquaculture system is called "ocean ranching" and is becoming a necessity because industrial pollution is spoiling the natural breeding habitats for salmon.

Seaweed culture is carried out in many parts of the world particularly in Asia where seaweeds are used as food. Seaweeds are algae and they are rich in vitamins and minerals; however, they are not popular as food in the United States. Certain seaweeds (brown and red algae) contain hydrocolloids (e.g. agar-agar, carrageen, and other alginates) which are commercially valuable. Industries in the United States have been harvesting seaweeds from natural beds off of the California and New England coasts for several decades. These seaweeds are extracted for their hydrocolloids which have application as stabilizers in many food products as well as in other commercial uses. For the past couple of decades, various methods have been devised, including aquaculture of seedlings, to enhance the growth of seaweeds in their natural beds. Hawaii has an active aquacultural program for the culture of seaweed for both food and commercially valuable products.

One of the most interesting seaweed aquacultural projects receiving world-wide acclaim is being carried on at Woods Hole, Massachusetts, by Dr. John H. Ryther of the Woods Hole Oceanographic Institution. Seaweeds and phytoplankton (marine algae) are used in final (tertiary) wastewater treatment to remove nutrients from the sewage as part of the purification system. The seaweeds can be extracted for valuable hydrocolloids or used as fodder in animal feeding. The phytoplankton is fed shellfish (primarily bivalve mollusks) and other marine animals. This marine polyculture system effectively cleans up the final sewage effluent being discharged into marine waters while at the same time producing useful products.

WASTEWATER TREATMENT:

In addition to research on marine polyculture for tertiary sewage wastewater treatment, other freshwater aquatic plants are being explored for the treatment of industrial and municipal wastewaters. Water hyacinths and duckweeds, both considered to be nuisances because they overgrow and clog waterways, are prime candidates for applications in wastewater treatment. They have the ability to assimilate vast amounts of nutrients from wastewater. Water hyacinths also have the ability to assimilate a variety of metal ions. This characteristic makes them useful for the treatment of industrial wastewaters such as from metallurgical industries. The water hyacinths absorb the metal ions from the wastewater and, in turn, valuable metals can be recovered by ashing the harvested plants and refining the ash for metal recovery.

Aquatic plants being grown in wastewaters are also being considered for biomass in energy production. Plant materials can be dried and burned as fuel. Perhaps even of more interest, they make excellent substrates for methane gas production by anaerobic fermentation. Other considerations for utilization of aquatic plants include food for humans, fodder for animals, fiber for industry, fertilizers for agriculture, and extracted chemicals for a variety of industrial uses.

U.S. AGENCIES RESPONSIBLE FOR AQUACULTURE:

Originally the National Marine Fisheries Service (NMFS)--as the former Bureau of Commercial Fisheries (BCF) under the Department of Interior--was responsible for all aquaculture projects. When the BCF was reorganized in 1970 as the NMFS under the National Oceanic and Atmospheric Administration (NOAA) of the Department of Commerce, it no longer had jurisdiction over freshwater fisheries. The jurisdiction of freshwater aquaculture (e.g. catfish farming) was turned over to the U.S. Department of Agriculture (USDA), Agricultural Research Service (ARS). The USDA, ARS has been sponsoring an active program in freshwater aquaculture since 1970. Meanwhile, the NMFS has been involved in some mariculture projects primarily at their own facilities.

The Office of Sea Grant Programs (OSGP), also under NOAA, has jurisdiction over a wide variety of marine-related research. OSGP sponsors research on aquaculture through state universities and other research institutions. Sea Grant sponsored projects include primarily marine aquaculture, although some freshwater projects related to anadromous species have been sponsored.

Although aquaculture has not been a major industry in the United States, there is an increasing amount of American research and development "know how" to improve aquacultural technology. It is being recognized that aquaculture is an efficient way for producing protein and vegetable foods. There are also other attributes of aquaculture, such as efficient wastewater treatment, which make technological improvements in this area desirable. The American experience of improving agricultural technology undoubtedly is trans-

ferable to aquaculture. If the impetus is kept up, America will remain the world leader in food production and food resource technology.

SUGGESTED READING

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6. U.S. Environmental Protection Agency, *Aquacultural Systems for Wastewater Treatment*: Seminar Proceedings and Engineering Assessment (MCD-67), University of California, Davis, September 11-12, 1979 (Washington, D.C.: Environmental Protection Agency, Office of Water Program Operations, Municipal Construction Division, 1980).

A trout called Kamloops is being studied as a potentially new commercial fish that could rival existing trout varieties. At the University of Idaho, George W. Klontz (right) points out the advantages of a Kamloops trout held by student Steven Swartz. Klontz, who is on the Idaho Agricultural Experiment Station's staff and heads the university's Department of Fishery Resources, is investigating the trout's potential in a three-year study. He has nicknamed the Kamloops, which is faster growing than the rainbow trout, the "Aberdeen Angus" of the fish world. It is expected taht the Kamloops could be ready for commercial production in the spring of 1982. (Courtesy, S&E Newsmakers, USDA, September 1981)

PRESERVATION OF AQUACULTURAL PRODUCTS

BY

F.W. WHEATON AND T.B. LAWSON*

Aquacultural products taken in the broadest sense include any products from the aquatic environment. For the context of this paper, however, aquacultural products will be limited to products derived from living or very recently living organisms. Although both plant and animal products are harvested from aquatic systems, the principle emphasis herein will be on animal products.

Preservation of aquatic products is very important since it is widely recognized that most fish, shellfish, and crustaceans harvested commercially deteriorate rapidly. This is due to the following factors: the chemical structure of the flesh (e.g., the high percentage of unsaturated fats present in the flesh); the excellent growth medium of the flesh for putrefactive bacteria; the presence of active enzyme systems which break down the flesh. Preservation of aquacultural products relies on several well-known processes. Chilling and freezing are the most widely known processes, especially in the United States. Several other processes, however, are widely used. Salting, smoking, and dehydrating are processes which have been used for centuries. Canning is also widely used to preserve aquatic products. Modified atmospheres and gas exchange processes are much newer, especially as applied to aquatic products.

The increasing importance of aquaculture, as opposed to traditional fisheries, as a source of aquatic products will have increasing importance in preservation of fishery products. Aquaculture can produce a more uniform raw product and, in many instances, can control the time of year at which the product is marketed. Movement of product from growing area to processing plant is much more rapid. For example, farm raised catfish are delivered live to the processing plant while ground fish from Georges Bank may have been held on ice several days before reaching the same plant. Aquaculture systems can, in many cases, be designed to provide a much more uniform flow of product to the processor and market. This helps stabilize the processing volume per unit of time, reduces plant size and down-time, and spreads capital costs over more units of product. It also enables the processor to secure and keep customers needing a year-around supply. Commercial outlets such as restaurants, fast food chains, and institutions find year-around suppliers more attractive than seasonal suppliers. As aquaculture production continues to increase relative to fisheries' production, these characteristics will strongly influence processing of aquatic products.

The relative importance of various preservation techniques in the United States can be estimated from Table 1. Fresh and frozen products constitute over 50 percent of the edible fishery products in the United States. Catfish and trout aquaculture industries in the United States market almost all of their products as either fresh or frozen. Canned products, composed principally of tuna, salmon with some shrimp, herring, gefilte fish, mackerel, clams, oysters, and crabs account for significant production in the United States. Cured products which would include salted, smoked, pickled, and similar products account for a smaller portion of the production in the United States.[1]

Table 1. Value of Edible Processed Fishery Products in the United States, 1980.[a]

Processing Form	Value (Million Dollars)	Value (% of Total Fishery Products)
Fresh and Frozen	2,387	50.9
Canned	1,792	38.2
Cured	118	2.5

[a] Source: *Fisheries of the United States*, 1980 (1981), *ibid.*

Cured products are much more important in the less developed countries where refrigeration is not widely available. Cured aquatic products tend to be expensive speciality products in developed countries but are important protein sources in less developed countries. In the Far East, many cured aquatic products also serve to enhance a rather bland cereal diet.[2]

CHILLING

Chilled aquatic products are those products preserved by lowering product temperature to near but not below the freezing point. Lower temperatures reduce bacterial growth rates and retard deteriorative enzymatic reactions, thus extending product shelf life. Chilling may be accomplished with ice, mechanical refrigeration, or a combination of both. Ice is usually preferred because, when properly applied, it cools to just a few degrees above its freezing point, it is simple to use, and it maintains a high humidity around the product, an important factor in maintaining product quality.

Shelf life of chilled aquatic products is determined by the animal species, how well the icing is carried out and maintained, how quickly the product is iced after harvest, air temperature and movement over the product, and other factors. Shelf life of cod under excellent icing may be up to 15 days while shelf life of certain herring may be only two to four days.[3] Quality deterioration usually results from activity of spoilage microorganisms, enzymes, or oxidation of unsaturated fats producing rancidity and/or off odors.

Chilling is the most widely used preservation technique for extending shelf life of raw fish, shellfish, crustaceans, and other aquatic species. It is relatively inexpensive, simple, and can be applied without elaborate equipment. It does, however, provide only limited shelf life extension.

FREEZING

Freezing extends shelf life by retarding bacterial, oxidative, and enzymatic activities due to low temperatures. In addition, freezing ties up water in ice crystals making it less available for bacterial and/or enzymatic processes. Since more water is crystallized out and the bacterial, oxidative, and enzymatic processes are increasingly slowed with

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decreasing temperature, shelf life is generally increased with decreasing temperature.

Unfortunately, the cost of freezing and storage increases as product temperature is lowered. Cost is thus in direct opposition to product preservation needs. A compromise is necessary and, for storage of most frozen aquatic products, a -23°C[4] to -30°C[5] is recommended. Higher temperature storage results in more rapid quality deterioration.

Shelf life of frozen aquatic products is a function of the species, processing employed prior to freezing, temperature history of the product prior to freezing, type of product (e.g., whole fish or fillet), fish species, temperature cycling in the freezer, product packaging, and other factors. Table 2 gives some average shelf life values for several aquatic products receiving reasonable treatment prior to and during freezing.

Table 2. Approximate Storage Times for Frozen Packaged and Glazed Fish and Shellfish.[b]

Product	Storage Time in Months at -18° [a]
Fatty Fish	
Mackerel	2-3 (4-6)
Salmon	2-3 (4-6)
Sea herring	2-3 (4-6)
Trout	2-3 (4-6)
Lean and Medium Fatty Fish	
Cod fillets	3-4 (7-10)
Haddock fillets	3-4 (7-10)
Fish sticks	3-4 (7-10)
Ocean perch fillets[c]	3-4 (7-10)
Sole	3-4 (7-10)
Striped bass fillets	(9)
Shellfish	
Shrimp	3-4 (6-8)
Scallops	3-4 (6-8)
Clams	2-3 (4-6)
Lobster (cooked)	2-3 (4-6)
Oysters	2-3 (4-6)
King crab	(6)
Dungeness crab	(6)

[a] Numbers without parentheses refer to storage time where hardly detectable quality changes occur. Numbers in parentheses refer to storage times where very significant quality changes occur.

[b] Reference: D. K. Tressler, W. B. Van Arsdel, and M. J. Copely, eds., *The Freezing Preservation of Foods*, Vol. 2 (Westport, Conn.: AVI Publishing Company, 1968).

[c] Reference: ASHRAE (1978), *op. cit.*

Frozen storage is popular in more developed countries where freezing, frozen storage, and transport systems are readily available. It is not widely used in underdeveloped areas both because facilities are not available to freeze and store frozen products and because of the expense involved.

Freezing is popular because it preserves products for extended periods and the product at the consumer level closely approximates a fresh product. Thus, frozen products are generally readily marketable. Freezing is relatively energy expensive and good packaging and environmental control are required to prevent freezer burn (i.e., dehydration of the product's exterior), formation of ice within the package, and other product quality changes during storage. Freezing also is capable of preserving products long enough that market gluts and shortages so characteristic of fisheries and, to a much more limited extent, aquaculture can be evened out by storing products during high production periods.

Fish are frozen by a variety of methods which, to a certain extent, determines the quality and storage life of the frozen product. The terms "quick freezing" and "slow freezing" are fairly common and refer to the length of time that is taken to freeze the product. There is no hard and fast definition for quick freezing but is usually refers to bringing the product to a temperature below 0°C within two hours or less.[6] The slow freezing process may take eight to 12 hours, or even 24 hours in some poorly designed freezers. Much controversy surrounds the question whether there are any advantages to quick freezing. It was once thought that the longer freezing times resulted in a greater protein denaturation but this argument still goes on.

Certain quality changes occur in frozen fish and shellfish while frozen. Toughness, stringiness, and loss of moisture by drip occur as a result of cell rupture due to ice crystal formation in the flesh. Off-flavors and color changes occur as a result of protein denaturation and, in fatty fishes, oxidation of the lipids produces rancidity, odor, and off-flavor. In addition, if the product was of poor quality, is not maintained at a low enough temperature, or was infected by large populations of microorganisms at the time of freezing, spoilage due to microbial activity can occur.

Some products do not freeze well. Oysters and blue crab meat are two examples. Oysters often become tough and rubbery when frozen; therefore, very small volumes of oysters are sold in the frozen state. Blue crab meat does not keep well and often becomes stringy and chewy when frozen. Most blue crab meat is pasteurized and placed in rigid plastic containers to be sold chilled rather than frozen. Properly pasteurized and chilled blue crab meat has a storage life of up to six months.

CANNING

There are a great many fishery products which are preserved by canning. Some of the more popular canned aquatic products include tuna, sardines, anchoveta, clams, salmon, shrimp, crab, and herring. To a lesser degree, other "gourmet" or speciality items are also canned, such as lobster, squid, octopus, eel, and smoked items such as oysters and rainbow trout.

Canning preserves foods by heat destruction of bacteria and enzymes which may be capable of spoiling the canned product. In some products, preservatives such as salt, glutamate, oils, or acids may be added to further prevent spoilage or to reduce the heat treatment needed since heating may cause undesirable changes in product texture or flavor. Foods which are hermetically sealed in a container include microorganisms and enzymes which, unless they are destroyed, will thrive in the environmental conditions afforded and will cause spoilage of the food. After canned foods are sterilized and the enzymes deactivated by heat, the container protects the food from spoilage due to recontamination by microorganisms. The food may then be stored for several years if not subject to extreme environmental conditions or if the container is not ruptured.

The botulism organism *Clostridium botulinum* is the organism of most concern to commercial canneries. This organism will not grow at a pH lower than 4.6 but, at the higher pH ranges (fishery products typically fall in the pH range of 5.0 to 6.8), canning must be done under pressure at a temperature above 100°C in order to insure destruction of the spores. *Clostridium botulinum* is highly resistant to heat; therefore, a sterilization process that assures destruction of this organism also kills most other microorganisms capable of producing canned food spoilage under normal conditions of canned food handling and storage.[7] In order to destroy the bacteria throughout the entire can, thermal treatment must be at least equivalent to four minutes at 120°C or 10 minutes at 115°C.[8]

Raw fishery products are, by nature, extremely perishable and must be handled rapidly under clean conditions if decomposition or contamination is to be avoided. Sanitary handling and proper processing before canning will insure that a minimum number of microorganisms will enter the can with the food. It is important that the bacterial number in

food prior to canning be as low as possible since a more intense thermal process will be required if microorganisms are present in large numbers.[9] Sterilization of canned food products is accomplished by the use of high pressure steam in a retort. It is important that the sterilization process be carried out in the shortest possible time since most fishery products are adversely affected by heat. Processing times and temperatures for some seafood products are shown in Table 3. Figures given are for products at an initial temperature of 21°C. The initial temperature determines, to a large extent, the time and temperature of the retorting process.

Table 3. Process Times and Temperatures for Various Seafood Products.[a]

Product	Time (Min.)	Temp. (°C)
Clams		
(No. 1 can)	50	116
(No. 2 can)	60	116
(Florida)	90	121
Crabs		
(No. 1/2 can)	35	121
	45	116
	80	110
Fish Flakes		
(No. 300 can)	75	121
	90	116
Lobster		
(No. 300 can)	75	121
	90	116
Oysters		
(No. 1 can)	30	116
Salmon		
(No. 1/4 can)	35	121
(No. 1/2 can)	60	121
(No. 1 can)	85	121
Sardines		
(No. 1/4 can)	40	116
(No. 3/4 can)	55	116
Shrimp		
(No. 1 can)	14	121
(No. 5 can)	7	121
Tuna		
(No. 1/4 can)	40	121
(No. 1/2 can)	55	121
(No. 1 can)	80	121

[a] Reference: Lopez (1975), *op. cit.*

Cans are typically made of steel with a thin coating of tin. When stored in tin cans, seafood frequently develops a condition called "black iron sulfide" discoloration which results when chemical interactions take place between the food and the can. Oleoresinous enamels--"C" enamels--used to coat the insides of tins used for seafood products prevent these chemical reactions. "C" enamels contain about 15 percent zinc oxide which reacts with the sulfides formed during heat sterilization to produce harmless white or colorless zinc compounds. The use of aluminum cans also prevents discoloration of seafoods.

Spoilage of the seafood stored in cans can occur if the product is improperly handled or processed before sterilization. This may manifest itself in the form of discoloration or spoilage. Bloating of the can may occur if gas is formed. Spoilage may also occur if the sterilization process is not properly carried out at the proper temperature or for the proper amount of time. In addition, if cans are ruptured or not sealed properly, spoilage can occur.

Canned products are, by the nature of the process, cooked. Thus, the product is not in any way considered to be fresh and has significantly different characteristics than a fresh product. Canned aquatic products are very stable, generally lasting for years under reasonable use. Since they can be stored at ambient temperatures, continuous energy input during storage is not necessary as it is for frozen products. Canning is a relatively simple process and with reasonable precautions can provide storage-stable products and can be produced without extensive processing training of personnel. It does, however, require heat (energy), retorts, and sealing equipment as well as a source of cans, lids, and labels.

DRYING

Drying, the removal of water from products, has been used for centuries for preserving fishery products. It is still today an important preservative process. Adequate drying will remove enough water to prevent microorganism growth on the product surface. Enzymatic reactions are also slowed dramatically since insufficient free water is available to allow free movement of enzymes. Most common spoilage bacteria are inhibited at water activities of 0.90 or lower. Molds are generally inhibited on fish at water activity values of 0.8 or lower.[10]

Drying is often thought of as an evaporation process. Although evaporative drying is widely used, osmotic forces can also be used. Salting of fish, an osmotic drying process, is widely used for producing salted, smoked, and fermented fish products. Simple drying systems consist of spreading gutted and headed fish on rocks or the ground and allowing the sun to evaporate the water. This system is obviously dependent upon weather conditions. High humidities, cloudy days, and/or lower air temperatures reduce drying rates. Thus, sun drying is limited to warm dry climates. It is also unreliable and the product is subject to insects, rodents, and other damage during drying. Large fish cannot be dried rapidly enough, unless cut into thin strips, to prevent spoilage. Contamination from sand, soil, and other materials is also a major problem with this technique.

The introduction of drying racks which held the fish a meter or more off the ground increased the drying rate due to increased air circulation around the fish. It reduced contamination problems but did not eliminate them. Drying racks of plastic coated wire mesh, rope net, or wooden sticks are used in many parts of the world today for natural drying of fish.[11]

Convective air drying is also carried out in mechanical dryers of varying degrees of complexity. Simple enclosed tunnels, through which air is forced when ambient air conditions are conductive for drying, are used in some areas. Other areas, particularly areas having high humidities much of the time, use enclosed drying tunnels with temperature and humidity controls and at least partial recirculation of the air. Cost is a major consideration in drying fish. Thus, the simplest and least expensive practical drying system generally is used.

Because fish, shellfish, and aquatic meats spoil so rapidly, air drying may not be rapid enough to dry the product before it becomes inedible. Salting is thus often used as a preliminary treatment prior to evaporative drying to remove water and to extend product shelf life prior to drying to a stable moisture content. Salting is discussed in detail below.

Dried fish often deteriorate due to molds, bacteria, insects, rancidity development, discoloration, or texture changes. Molds generally will not grow on meat at equilibrium with relative humidities below 65 percent. At equilibrium moisture contents of about 75 percent, most molds grow well but bacteria generally require higher moisture contents. Moisture protection must be provided if the dried products are to be shipped to areas having relative humidities over 65 percent. Packaging is thus of major importance. Good packaging also will reduce loss from insects, rodents, and other animals. Packaging can also reduce rancidity development and some texture changes.[12]

Dried fish should not be compared with fresh fish because it

is a totally different product. Once dried it cannot be reconstituted as a fresh product. Drying generally produces some irreversible hardening of the protein. Reconstituted dried fish generally have a harder texture than do fresh fish. As a general rule, the more rapidly the drying occurs the better the fish reconstitutes.[13]

The flavor of dried fish is also often different than that of fresh fish. The desirability of limiting both flavor and flavor and texture changes is a function of the market requirements. Many dried fish consumers find some rancidity development desirable due to the distinct flavor imparted by this process.[13] Thus, detailed knowledge of the market preferences is necessary to determine the most desirable processing techniques.

Drying is probably used more widely in processing of aquatic products destined for industrial uses rather than for food uses. The most well-known of these products are fish solubles and fish meal. Fish such as menhaden and anchovies are harvested in large quantities and processed to produce fish oil, fish solubles, and fish meal. Fish solubles and fish meal are the products left after extraction of the fish oil and are used extensively as protein supplements for agricultural animal feeds. After oil extraction, the wet fish solubles and fish meal are dried in rotary hot air dryers to stabilize them for storage.

SALTING

Salting fish is the process of treating the fish with dry salt or a salt brine to remove water by osmosis and to diffuse salt into the flesh. Although salt has some inherent preservative properties, its major preservative action is due to a reduction in moisture content.[15] Fish are generally gutted, headed, and split prior to dry salting. The split fish are then stacked about one meter deep and kenched with alternating layers of salt and fish. Depending on the process used, the stacking may be done on a flat surface or in a tank. If stacked on a flat surface the water extracted from the fish by osmosis and squeezing from the weight of the fish above is allowed to drain off. If stacked in a tank the brine formed is collected in the tank and soon submerges the pile of fish. Salt content of the brine is adjusted to the desired concentration for the salting process. Heavy salting will result from saturated or near saturated brine while light salting requires much less salt. The length of time the fish are left in the stack varies from a few hours to several weeks, depending on the salting process. Light cured salt products, such as the "Gaspé cure" used in Canada, may have salt contents as low as five percent wet basis. Heavy salt cures will have salt contents of 20 to 25 percent wet basis or higher. Light salt cured products have a short shelf life and must be held under refrigeration. Light cures are used primarily for producing dedired product flavors rather than preservation. Heavy salt cures can be stored at ambient temperatures for several months, particularly when evaporatively dried after salting and packaged to prevent moisture absorption.

Salt removes water and causes denaturation of protein, at least at salt contents above seven to 10 percent wet basis. Thus, salted products will not generally reconstitute to a product closely resembling the fresh product, particularly heavy salted products. Light salting is often used under closely controlled conditions to allow some product deterioration. This controlled deterioration imparts desirable flavors to the product. Poor environmental control of these products results in a spoiled unsalable product. Thus, process control to achieve the desired cure is much more critical in light salted than in heavy salted products.

Impurities in the salt such as magnesium, calcium, and sulphate ions may influence flavor and color of the salted product and will influence the rate of salt penetration into the flesh. These ions impart a bitter taste to the fish, cause a tougher texture, and produce a lighter colored product. Some salts, particularly salt evaporated from sea water, usually contain some halophilic bacteria. These bacteria are pink in color and as they grow are referred to as "pink." Salts derived from underground mines generally do not contain "pink."

Salt fish generally is dried by evaporation after salting to stabilize the fish for extended storage. In fact, salting has been practiced for centuries as a temporary preservation method which will prevent spoilage long enough to allow sun drying of fish. In many countries of the world, particularly in tropical underdeveloped countries, salting still serves this purpose. In more developed countries where freezing and canning are more widely used, salting generally is used to produce specialty products. Brine salting is widely used as an initial step in the production of fermented fish products, particularly in the Far East.

The deterioration of salt fish depends on the salt content and the drying process used. Light salt fish--salt contents below five to seven percent wet basis--deteriorate in a similar manner to fresh fish. Thus, temperature control is essential until these products are dried or consumed. Their shelf life is a matter of a few days unless dried. Salt fish having salt contents from seven or eight up to 12 to 14 percent wet basis generally have sufficient salt content to inhibit most of the normal spoilage bacteria found on fresh fish. Bacterial decomposition is retarded until the more salt tolerant spoilage microorganisms can grow. Heavy salted products have enough salt to inhibit all but the halophiles. Thus, spoilage will occur if sufficient water is available on the product's surface but it is considerably slower in developing. "Pink" probably is the most common type of halophilic spoilage bacteria. Although it does not produce toxins and, in early stages, can be removed by washing, extensive contamination by "pink" putrifies the product making it unfit for sale or consumption. "Dun," a halophilic mold, also is troublesome on salt fish having five to 10 percent of higher salt content. Although "dun" does not decompose the product like "pink," it produces unsightly brown or black spots on the product, rendering it unsalable.

SMOKED FISH

Smoking fish is a process in which fish are dried and subjected to smoke generated from a non-resinous wood or other fuel during drying. Wood smoke consists of vapors and tarry droplets with the same chemicals present in both but in different proportions. The chemical substances most easily evaporated are available in the vapors. The vapors are trapped by moisture on the product surface and impart desirable flavor and color properties to the smoked product. The tarry droplets in the smoke are not an essential part of the smoking process.[16]

The preparation of fresh aquatic animal flesh for smoking depends on the smoking process to be used, the fish size and species, the type of smoking equipment used, operator experience, and other factors. Regardless of the process to be used, there is a greater probability of producing high quality products if the fish or other product entering the process is fresh and of high quality.

Fish are prepared in a variety of ways for smoking. Some species are gutted and headed, some are smoked as harvested, some are gutted only, some--particularly in large fish--are cut into smaller pieces to provide a greater surface area to volume ratio, a process which speeds the smoking and drying rates. Once prepared in the desired way, fish are often placed in a salt brine or packed in dry salt for a period of time. The salting time and the salt or brine strength used varies with the final product desired and other variables. The salt or brine application removes water from the fish much more rapidly than can be removed by evaporation during smoking, a significant advantage in warm climates. Some fish are sun dried prior to smoking while, in more developed countries, mechanical dryers may be used to lower the moisture content prior to smoking. This prevents the fish from spoiling in the smoker before they are sufficiently dry to prevent bacterial growth.

Smoked products are produced by placing fish or other products on wire mesh racks or by hanging them from rods or sticks and placing these in an enclosure used for smoking. A fire in the bottom of the enclosure or smoker heats incoming air, thereby lowering its relative humidity. As the air passes upward over the product, it evaporates water from it. In some processes, small wood chips or other material are

placed in the fire as soon as it is started to generate smoke. In other processes, drying continues for a period of time, varying from a few minutes to a few hours, prior to introduction of the smoke-generating materials.

There are two general types of smoking processes used: cold smoking and hot smoking. Cold smoking consists of a light brining followed by slow drying and smoking with the smoking and drying temperatures not exceeding about 29°C. Cold smoked fish are not cooked. Kipper, lachshering, bokking, cold smoked salmon, haddock, cod, shrimp, and roe are all examples of cold smoked products presently on the market.[17] Weight losses of five to 20 percent during smoking are usual for cold smoking processes. Since their final moisture content is quite high, their shelf life unless further processed is on the order of two to 10 days, depending upon the product, storage conditions, amount of moisture removed during drying, and other factors.

Hot smoking consists of drying and smoking at temperatures of 80° to 90°C or higher. The product is cooked, a process which deactivates the enzymes responsible for autolysis of the flesh. Cooking also kills most bacteria on or in the product. Thus, hot smoked products are ready to eat and require no further cooking. Smoking is usually completed in three to four hours and often in two hours or less.[18]

A wide variety of products are produced by hot smoking among which are buckling, fleckhering, anchovies, eels, salmon, trout, halibut, smelt, oysters, razor clams, and shrimp. Details of the smoking process vary with species, geographical location, and many other variables. Details for hot smoking several species are available in references listed below.[19]

Table 4. Approximate Storage Life of Several Species of Smoked Fish.[a]

Species	Smoked Product	Storage Life 16°C: In First Class Condition	Storage Life 16°C: Remains Edible	Storage Life 0°C: In First Class Condition	Storage Life 0°C: Remains Edible
		Days	Days	Days	Days
Cod	Single fillets, cold smoked	2-3	4-6	4-6	8-10
Haddock	Single fillets, cold smoked	2-3	4-6	4-6	8-10
	Block fillets, cold smoked (golden cutlets)	1-2	2½-3	4	6
Herring	Kippers and kipper fillets, cold smoked--unwrapped	2-3	5-6	4-6	10-14
	cold smoked--wrapped	1-2	3	3	3-44
	Bloaters, cold smoked	1-2	2-3	3-4	5--6
	Buckling, hot smoked	1-2	2-3	3-4	5--6
Salmon	Fillets, cold smoked	2-3	4-5	4	10
Trout	Whole, gutted, hot smoked	3	7	6	10

[a] Source: [FAO], *Smoke Curing of Fish* (1970), *op. cit.*

Shelf life of hot smoked products depends on the amount of processing received following smoking. Weight loss during hot smoking is often in the range of 20 to 40 percent. Many hot smoked products are canned after smoking, thus extending their shelf life greatly. Tables 4 and 5 give the general storage life of various smoked products when held at the indicated temperatures.

high enough to inhibit their growth. Since bacteria which are salt resistant tend to be sensitive to low pH and vice versa, a combination of high salt concentration, low pH, and absence of oxygen favors growth of the desired bacteria.[22]

Fish muscle protein falls into essentially three groups: myofibrillar proteins (65 to 75 percent), myogens or sarcoplasmic proteins (20 to 30 percent), and connective tissue proteins (five to eight percent). Only the myogens are soluble in solutions containing less than 0.5 percent salt. Myogens also contain most of the proteolytic enzymes of the muscle. Connective tissue proteins are not soluble in salt solutions of any concentration. Myofibrillar proteins, such as myosin, actin, and tropomyosin are influenced most by changes in salt concentration. Thus, as the salt concentration rises, myofibrillar protein solubility rises, reaching a maximum of between three and 12 percent depending on the temperature and the species. Above 12 percent, salt solubility of protein falls due to increasing precipitation within the tissues. In saturated salt solutions, most proteins are precipitated within the muscle.[23] Protein extraction from fish is also pH dependent with maximum extraction occurring between seven and nine and a rapid drop in solubility between six and five. Thus, in fermentation processes using less than 20 percent salt, some protein will dissolve, the amount being a function of pH and temperature. At higher salt concentrations, most proteins will be precipitated in the muscle.[24]

Table 5. Approximate Storage Life of Frozen Smoked Cured Fish Made from Good Quality Raw Material.[a]

Type of Fish	-9.5°C Good	(15°F) Inedible	-20°C Good	(-5°F) Inedible	-29°C Good	(-20°F) Inedible
Smoked white fish	1 month	3 months	3½ months	10 months	7 months	more than 1 year
Smoked fatty fish	3 weeks	2 months	2 months	5 months	4½ months	more than 9 months

[a] Source: [FAO], *Smoke Curing of Fish* (1970), *op. cit.*

In addition to hot and cold smoked products, there is a wide range of traditional products produced using smoke-drying. These products may be smoke-dried, combined smoke/sun dried, or boiled and smoke/sun dried. Products such as bonga (Africa), smoked milkfish or bandeng (Indonesia), Pla-krob (Thailand), katsuobushi (Japan), and tinapa (Philippines) are but a few of these products. Details of their processing can be found in references listed below.[20]

FERMENTED AQUATIC PRODUCTS

Fermented aquatic products can, in simple terms, be defined as the transformation of organic substances into simpler compounds by the action of enzymes or microorganisms. In recent years, chemical methods have also been employed to help bring about the desired changes. Fermentation preservation is inexpensive, requires low levels of technology, calls for no chilling, and does not need complex transportation and storage facilities. Most fermented products are salted before or during the fermentation process. Processing times are generally long, on the order of months to a year or more. Thus, traditional production methods do not lend themselves to production line processing.

Fermentation processes in fish are controlled primarily by the salt concentration. Generally, the typical spoilage organisms on fish are not salt tolerant, while the more salt tolerant microorganisms are less objectionable. In many cases they are even desirable. Additionally, salt concentrations of six percent salt inhibit most, but not all, enteropathogenic bacteria.[21] Some of the less desirable halophilic bacteria, such as "pink," and molds, such as "dun" or "mite," are inhibited by low oxygen. Thus a large number of fermented products are produced in closed containers or at least submerged in brine which is not stirred. Additionally, under anaerobic conditions, lactic acid-producing bacteria tend to predominate. The pH decreases helping to preserve the product.

Fermented products produced under too low a salt content allow normal spoilage bacteria to grow and putrefy the product. The availability of oxygen allows aerobic yeasts, molds, and bacteria to grow which can metabolize the acids produced by the lactic acid bacteria. The pH rises allowing putrefactive bacteria to grow if the salt content is not

Enzymes also play a major role in production of fermented fish products. Enzymes of the viscera and digestive tract such as pepsin and trypsin play important roles in liquifying some fish products such as "nuoc-mam." Neutral or alkaline conditions appear to encourage maximum activity of these enzymes in fermented fish products. Variation in enzyme activity with feeding activity, season, spawning cycle, and other factors help make fermentation processes an art as well as a science. Muscle tissue enzymes also play a role in fermentation although probably a less important role than viscera and digestive enzymes, mostly because their range of greatest activity tends toward acid conditions.[25]

Plant derived enzymes such as bromelain from pineapple juice, papain from papaya, latex and ficin from figs are also added to some fermented products to help break down the fish flesh. Enzymes secreted by microorganisms such as certain species of fungi, bacteria, and yeasts are also potent sources of proteolytic enzymes which are active in some fermentation processes.

There are three general types of fermented products widely produced: sauces, pastes, and whole fish. Specific products are often characteristic of various geographical areas as are the specific processing procedures. Nuoc-mam is a typical ex-

ample of a fish sauce. Fish are mixed with salt in alternating layers of fish and salt, typically four to five parts salt to six parts fish, in a large tank. The mixture is allowed to stand for about three days when some of the liquid portion is poured off. The fish are packed and enough of the saved liquid is poured back on the fish to cover them well. Weights are placed on the fish and the tank is left to ferment. Periodically the tanks are tapped and some of the fermented liquor drained off. This is first quality nuoc-mam. With small fish, nuoc-mam can be produced in a few months while, with large fish, a year or more may be required.[26]

The storage life of fish sauces depends on their salt content, storage conditions, and other factors. Some sauces can be kept in good condition for up to two years. Nuoc-mam starts to lose its nutritive value after about five months.[27] Fish sauces such as "petis," "tuk-trey," "nam-pla," and others are widely used, particularly in the Far East, to flavor rice dishes and to provide protein. Fish pastes account for a smaller production volume but are more important nutritionally than sauces. They provide a significant portion of the daily protein intake, the percentage generally being in inverse proportion to economic status.[28]

Fish pastes include several partially dried products and residues left from sauce production. The fermentation process is dependent on the species used, temperature, whether the fish were gutted and/or headed prior to fermentation, and other factors. In some processes, plant materials are added to provide protolytic enzymes, carbohydrate, or flavoring.

"Bagoong" is a typical example of fish paste processing. Gutted fish of one of several species may be used. The fish are mixed with salt--one part salt to three parts fish--and placed in clay jars to mature. The fish break down into a paste, largely due to enzymatic activity, with some liquid formation. When the fermentation is complete, the liquid portion is used either as a sauce or discarded and the remainder is "Bagoong."[29] Shelf life of fish pastes varies depending on processing and storage variables. Storage life of up to six months to a year is not unusual.

Several whole fish fermented products are produced. "Sushi," a Japanese product, is one of these. Fish such as carp, sea bream, or sand fish are gutted and mixed with 20 to 30 percent by weight of salt. Fermentation is allowed to proceed for one to two months. The fish are then desalted and the liquor drained off. Boiled rice and "koji" are mixed with the fish and a second fermentation stage of about 10 days duration completes processing. Yeasts in the "koji" start the second fermentation. Space does not permit detailed description of the processing techniques used to produce many of the fermented fish products. Details of their preparation is available in references listed below.[30]

Fermented fish products fill a need for food materials capable of providing spice to diets dependent primarily on cereals. They also provide an important protein source in some areas of the world. They can be stored for extended periods without chilling or freezing, a significant characteristic in tropical underdeveloped countries. They are simple to prepare, require little in the way of technology or sophisticated equipment, and are inexpensive to produce but they do have relatively long processing times.

GAS EXCHANGE

The use of gas exchange as a preservation technique is an outgrowth of controlled atmospheric storage. The mode of operation, however, is somewhat different. Stabilizing various aquatic products requires deactivation of protolytic enzymes and control of bacterial decomposition. Gas exchange systems accomplish these functions by a series of evacuations and gas treatments. The evacuations remove oxygen and/or other gases from the intercellular spaces of the product. Gas treatments are designed to inactivate the enzyme systems and to kill bacteria, molds, and other microorganisms. Enzyme systems have been treated with carbon monoxide, carbon dioxide, sulfur dioxide or ethylene oxide.

It must be stressed that gas exchange treatment of aquatic products is very much in the basic research stage of development. Several problems must be overcome before any commercial application can be anticipated. Most research to date has been on fruits and vegetables with little or no research on fish, shellfish, or other aquatic products.

Gas exchange does not require temperature extremes as does canning or freezing, processes which cause texture and other quality changes. Eliminating or reducing the need for heating or cooling reduces energy usage for preservation. Storage of gas exchange treated products will probably be at ambient temperatures or, at worst, chilled temperatures. Estimates of shelf life are unavailable but could be in the range of from several weeks to several months.

MODIFIED ATMOSPHERES

Modified atmospheric storage of aquatic products is quite new but is being used commercially for a few products. It is an outgrowth of the controlled atmospheric storage of fruits--a process used commercially for over 30 years--and considerable research and application of modified atmospheres for extending shelf life of red meats and poultry.

Modified atmospheric storage of aquatic products, as employed today consists of packaging the product in a modified atmosphere as opposed to storing the product in bulk in rooms as is done with fruits. Most commonly, an atmosphere of 100 percent or at least elevated levels of CO_2 are used. Shelf life extensions of up to 10 days longer than fresh products have been experienced. An extension of six days of storage life, however, is more usual. Although the modified atmospheric storage of aquatic products is being used commercially there are many questions still being researched. The most desirable gas concentration to be used, the effects of elevated CO_2--especially 100 percent CO_2--on product quality, the benefits relative to the additional cost of increased CO_2, and the best types of packaging are just some of the questions being addressed by researchers. The extensive research results available on use of modified atmospheric storage of red meat must be transferred carefully and with adequate experimental results on aquatic products. Direct transfer of results is not possible because fish generally have very different bacterial flora than does red meat. In spite of these problems, modified atmospheric storage appears to be a promising method of extending shelf life of aquatic products, particularly fresh products.

SUMMARY

Aquatic products are preserved in several ways among which are chilling, freezing, canning, salting, smoking, fermenting, gas exchange, and modified atmospheric storage. Chilling, freezing, and canning are the primary methods of preservation in developed countries. Salting, smoking, and fermenting are used primarily for production of specialty products in developed countries but provide preservation of valuable protein in many underdeveloped countries. Gas exchange is an experimental method of preservation with considerable future promise. Modified atmospheric storage (or packaging), although in the early commercial stage at present, appears to provide significant shelf life extension.

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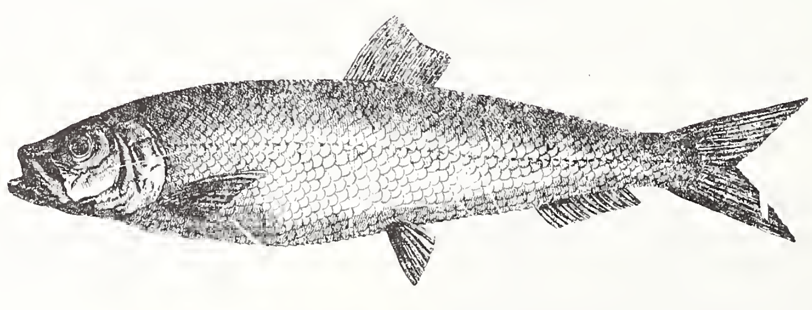

("Le Hareng" as found in Bonnaterre's Tableau Encyclopédique et Méthodique . . . Ichthyologie, *1788: Courtesy, National Agricultural Library, Rare Book Collection)*

CARP - A NUTRITIONAL FOOD SOURCE

PRELIMINARY STUDIES ON THE USE OF CARP IN THE AMERICAN DIET

By

BELA SZEPESI*

AQUACULTURE, POLYCULTURE, AND THE USE OF CARP AS A FOOD SOURCE

Carp is recognized in most countries not only as an edible fish but also as a choice edible fish. Several factors are compelling us in the United States to reevaluate this fish that Isaac Walton once referred to as "the queen of the rivers."

The world's total annual fish catch has reached a plateau of about 75 million tons. Due to a number of complex economic, political, and biological reasons this figure is not expected to increase appreciably in the next two decades. Fish consumption, the the other hand, is expected to more than double. It is widely hoped that by the year 2000 aquaculture will provide the nearly 100 million ton annual shortfall.

The production of marine fish in controlled environment is even now a reality.[1] Unfortunately this type of aquaculture has a number of limitations: 1) most species require a high-protein regimen which means the use of other fish or fish-derived products; 2) transportation of marine fish inland is costly because of the refrigeration requirement; besides, the shelf-life of marine fish is relatively short; 3) freezing such products causes texture or taste problems. It appears then that aquaculture of marine fish may increase fish availability in coastal areas, but not inland. Fresh-water aquaculture (the single-species culture method employed in the United States now) suffers from similar limitations as outlined for marine aquaculture: 1) trout and catfish require a high-protein regimen; 2) marketing the refrigerated product is costly; 3) marketing the frozen product introduces taste and texture problems. Polyculture, the raising of several species of fish that do not compete with each other, offers several advantages. It is several centuries old so we know that the method works.[2] By using fish that occupy different niches (physically) in the miniecology of a fishpond, more fish can be raised per unit area. Using various species of the carp family and catfish it is possible to raise catfish on a high-protein regimen and the carp on the algae and decomposition products that are derived from the decomposition of the high-protein regimen. Thus, while in single culturing of trout and catfish, food wastage is a loss and a problem which requires filtration (or other solution), in a polyculture the food wastage becomes an economic asset.

BARRIERS TO THE USE OF CARP

Raising catfish and two kinds of carp in the same pond and using the high-cost food made for trout, we estimated the cost of cultured fish to come to $.40/lb. Since 50-60% of the fish is edible this would bring the price to $.80/lb; with transportation and handling adding $.40, the grocery store cost would be about $1.20/lb. With improvements in the economy of production, transport, and marketing, a cost of $.75-$1.00/lb. is a good possibility.[3] At present there is no discernible effort to introduce carp into the American diet. One need not look far and long for the reason. The fact is that Americans consider carp inedible. A close family member of mine, who likes to eat fish, told me that she did not like carp. While her attitude was not atypical, it was nonetheless interesting that she never had tried carp yet had learned to dislike it.

Carp (the common "german" carp, *Cyprinus carpio*) was introduced into the United States during the last century. It was supposed to be used for fish farming and some were sent to practically every congressional district. Soon, due to floods or just carelessness, some of the fish escaped and established themselves in the rivers and lakes and began to disturb the habitat and spawning ground of other fish. Spawning carp roils the water and the resultant "muddying" causes other species to flee or die. Once grown to mature size (3-30 pounds) carp has virtually no enemies and tends to proliferate to the limit of its food source. Faced with such an ecological problem, fish and wildlife experts began a campaign of extermination that has proved futile but which is pursued even now. Many things have been tried--poisons; draining of lakes, dams; netting--but the carp endures and thrives.

The sociological aspects associated with carp did not help its image. A large amount of organic matter in a river causes a condition known as eutrophication. Under such conditions organic matter is decomposed at the river bottom largely anaerobically producing the "swamp smell." The problem is that species that feed at the bottom (such as carp and catfish) pick up this smell and taste. While legends on "purging" carp of such a taste remained among our fishermen, the knowledge of "how" was lost. Few who caught a carp in summer and tried to eat it would wish to repeat the experience. Summer carp and catfish became a fish of poor blacks.

Carp is such a hardy fish (because it can extract oxygen from its swim bladder as well as from its gills) that it is practically impossible to kill it by pollution. So, while our rivers became polluted, Americans came to think of polluted rivers and carp as inseparable. And who would eat fish from the Potomac when swimming is banned in the river because of pollution? Yet it is not the fish that causes the pollution; carp, like catfish, is free of noxious tastes and pollutants when grown in clean water free of pollution.

CARP AND THE NATIONAL AQUACULTURE PLAN

While the National Aquaculture Plan[4] calls for the investigation of all possible culturable species, we have a peculiar situation with carp. Here is a fish that abounds in our rivers but which is not even considered edible by our population. There is very little expertise on its use. The scientist, then, who asks for a million dollars to lay the foundations for a multi-billion dollar industry could very well end up getting a golden fleece. It was against such a background that I began my research three years ago. Most of the work that I am about to describe had to be done as a hobby for there was no administrative mechanism in existence in the Department of Agriculture to carry out the work.

THE TASTE OF CARP - FACTS AND FICTION

I will never forget the day in May when my father arrived for a two month visit from Hungary. I knew that he fished so I asked him if he'd like to go fishing. "Of course," was

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his response. "Well," I said, "what will we fish for?" He pulled his glasses down on his nose and looked at me over them as if I had just asked something self-evidnet. "Carp," he said. And carp we caught. In the nearby Patuxent River, one day, the two of us caught over 100 pounds of carp. We dutifully cleaned, battered, and fried one filet and I took a bite. How to describe the taste? Swamp? Mud? Perhaps. My father was very disheartened. Strangely enough, the carp that we caught in the Potomac tasted all right if a bit fishy. It was the same for the carp taken from a local reservoir. And that is how I first became acquainted with the yearly taste cycle of the carp. During summer, when most major rivers are eutrophic, carp takes on the "muddy" taste. During the late fall and winter, the eutrophying bacteria are killed by the cold and the "mud" taste is purged by the cleaner water. Carp will then remain free of the "mud" taste in the spring until the river again become eutrophic. In reservoirs, where organic matter inflow is restricted, the water never becomes eutrophic and carp never tastes "muddy."

After my father left in June, I began to study the purification of carp. According to my father and some other sources, keeping carp in a bathtub for a day should get rid of its "mud" taste. Unfortunately, carp will not live in a tub full of chlorinated water; besides, my family rebelled so I resorted to using a children's plastic swimming pool (eight feet wide and two feet deep) that I bought in a store. Soon I discovered (rediscovered?) the requirements of purging carp of its "mud" taste. These are as follows: 1) a sturdy pool with aeration; 2) a net cover on top (carp are good strong jumpers) which is secured tightly at the side so the fish can't slop out between the net and the side of the pool; 3) some kind of shade (a dark, thin, plastic sheet will do), and 4) a pinch of methylene blue to prevent bacterial growth. These are the requirements for purging carp at home. On a larger scale, the job is easier because holding tanks or other areas can be built economically if the structure is used continuously. I changed the water once a day but an overnight attempt to feed the fish killed them. Unlike conventional wisdom suggests, my fish had to be purged for a week before the "mud" taste was gone completely. So it can be done. Various other legends survive among fishermen as to how to get rid of the "mud" taste of carp: cutting out the blood vein on the side of the fish; soaking in salt water, vinegar, lemon juice, and so on. I tried them all. None of these methods works satisfactorily. The only solution is purging.

FISH FOR FISH HATERS

I suppose that most fish have a mild to strong fish taste depending on the freshness of the fish and the amount and type of fat in the fish. Carp also has a "fishy" taste which is quite different than the "mud" taste. Since my family consists of fish haters (I, myself, am not too crazy about oily fish), this presented an additional problem. Carp is a very bloody fish and it bleeds a good bit when beheaded. In addition, while the flesh remains pink from the blood in it, the blood vein on the side of the fish remains dark red from all the blood. There were hints in fishermen's legends that the fishy taste was due to the blood. My father and I tested this by lightly salting the scaled fish and letting it "bleed," rinsing the fish, and then cooking it. The method was not totally satisfactory. Then I tried the salting method on filets or skinned fish. Because I worried about adding salt to the diet, I experimented further and arrived at two methods of getting rid of the fish taste. Both methods use skinned filets: in one method, the fish is salted and then soaked in two changes of cold water; in a second method, the salting is omitted. In a practical home (such as ours), a four to six pound fish can be processed and parts of it soaked in a bowl in the refrigerator. The resultant nearly white flesh is appetizing and is free of fish taste. Both methods of soaking give equally satisfactory results with regard to taste.

Because of the soaking in water it was important to check the effects of these methods on the mineral composition of carp. Two of my colleagues in the Vitamin and Minerals Laboratory of the Nutrition Institute at Beltsville--Dr. Wayne Wolf and Mrs. Ella Green--were kind enough to collaborate with me on these studies. The results are shown in Tables 1 and 2. Sodium was gained with the soaking process and potassium was lost. Some zinc and iron also were lost in soaking but there was a slight gain in copper and manganese. We then wished to determine the effect of prior salting on the effects of sodium/potassium gain or retention. The results are shown in Table 2. Both sodium and potassium were lost during soaking without prior salting. On the other hand, prior salting doubled the final sodium content but had only marginal effect on the potassium loss. Inasmuch as excess sodium may pose a health problem for a number of individuals, the soaking of carp without prior salting may be preferable.

The results indicate that carp can be subjected to a considerable amount of processing without a great deal of alteration in some essential minerals (such as zinc and iron). Further work under conditions resembling certain industrial and marketing options needs to be done before settling on the optimal industrial and marketing strategies commensurate with nutritional requirements.

TABLE 1

Effect of Soaking, Brining, and Smoking on the Mineral Content of the Meat of the Common Carp (*Cyprinus Carpio*)

Treatment and Size (kg)		Mg/100g Tissue or Per Ml Fish Broth					
		Cu	Zn	Mn	Fe	Na	K
None[a]		.507	7.61	.0603	4.02	245	3,170
Soaked[b]		.394	6.33	.137	2.72	721	1,230
None		.364	9.67	.591	3.51	275	3,450
Soaked		.461	7.01	.182	2.85	1,700	569
None	2	.442	6.17	.301	2.78	339	4,600
Soaked		.755	5.48	.536	2.78	2,220	1,030
None	2	.362	7.72	.216	2.10	390	3,590
Soaked		.504	5.25	.480	3.02	2,890	1,440
Soaked, brined, and de-salted	2	.987	5.46	.145	4.18	8,692	141
Smoked							
low-salt brined		.501	5.44	.613	3.50	28,500	1,450
low-salt brined		1.02	18.4	.337	12.10	24,400	1,694
high-salt brined		.975	8.54	.877	5.18	35,400	2,180
high-salt brined		.529	22.8	.124	5.57	16,700	1,690
Fish broth		.330	.473	0	1.02	1,740	479

a
Fish were skinned, the head, fins, and tail were cut away, and the fish were then rinsed clean of blood. Usually a cut was made along (and close to) the backbone from head to tail resulting in a backbone piece and two filets.

b
Following the procedure described in footnote #1, the filets were then salted from a salt shaker, allowed to bleed one hour, rinsed, and soaked in cold tap water for 12 to 16 hours. The water was changed after two and six (or eight) hours.

TABLE 2

Effect of Prior Salting on Na and K Content of the Meat of the Common Carp (*Cyprinus Carpio*)

Treatment	mg/g Tissue Na	K
None	583	3035
Soaked without prior salting[a]	101	972
Soaked with prior salting	1150	1460

[a] These filets were treated as described in footnote #2 of Table 1 except that the salting was omitted.

CARP AS FOOD

Reviewing the cookbooks in the National Agricultural Library, I found the following recipes for carp: two Chinese; two Hungarian; Serbian carp; Bavarian Christmas carp, and Czechoslovakian Christmas carp. There were also recipes for Russian carp with currant sauce and carp with vegetables. There were two major problems with this: a) that the types of food available that could be made with carp were limited, and b) that we had the same problems with these recipes as we had with other foods: that the meat portion is considered the main food and vegetables are just a side dish--an afterthought. Our current nutritional recommendations, which I endorse, call for meat as a part of food but not necessarily the main ingredient.[5]

With this in mind, I set out to scour the world's literature on fish cookery and began the process of adapting fish cookery from Portugal to China for the use of carp. The resultant is a cookbook containing over a hundred recipes (with variations) for carp cookery. Aspics, appetizers, soups, stews, pies, turnovers, chowders, meat balls, stuffed vegetables, hamburgers, meat loaves, sausages, salads, and even taramasalata (fish egg spread). Eventually I tired of so much cooking and testing. The book could be doubled easily, I'm sure. It does show, however, that carp can be adapted to practically any taste. The cookbook, like much of the work dealing with carp, awaits an awakening of interest to show up in print.

Once I had a fairly representative sample of carp cookery, I put the ingredients into a computer program to calculate the composition of the various recipes. The results were gratifying. While pork may have 15 to 20% fat and beef has 8 to 14% fat, carp is listed as having only 5% fat and 20% less cholesterol than lean hamburger.[6] Also, by judicial inclusion of vegetables or bread, the caloric content can be kept at a reasonable level. While animal fat is more saturated, the fat in carp has a 1:1 ratio of saturated to unsaturated fat[7] which is to say, carp has the same degree of unsaturation as corn oil.[8]

THE FUTURE OF CARP IN THE UNITED STATES

As I tried to point out, there are economic, nutritional, and even political reasons for us to proceed with the development of carp as a food source in the United States. Certainly the basic ingredients of economic and nutritional need are there. We need funding and a structure to provide for basic studies in the educational process in order to get the project going. We have a unique opportunity to develop a food source practically from zero. This offers us a chance to avoid the mistakes of the past, mistakes that became so ingrained with other food sources that they were virtually impossible to correct (such as grain fattening of cattle). This means that in developing carp as a food source nutritionists should have a strong input during development. The National Aquaculture Plan, once vetoed by former President Carter, will probably become a casualty of the budget cutting in the early 80's. So, I end this article with an advertisement: "Potential multi-billion dollar industry has urgent need for tycoon with vision to initiate development. Some willing expertise available. Potential rewards great. . . ."

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CHEMICALS USED IN AQUACULTURE

By

A. JIM CHACKO*

Aquaculture had its beginning approximately four thousand years ago. The earliest known literature on the subject is that of Fan Lee from China dating back to 5th Century B.C. From the days of Fan Lee, aquaculture has developed into a full grown, commercially and recreationally oriented, high technology industry. It has evolved from the earlier simple single pond system into an intensive complex of raceways, in some cases even making use of the closed recirculating systems.

The crowding and growing of large numbers of fish in limited space have resulted in the usual accompaniments of diseases. Diseases of cultured fishes are caused by bacteria, fungi, virus, and parasites. Nutritional problems and associated diseases do not fall within the scope of this article.

The aquaculturist treats his fish with a variety of chemicals to prevent and ward off the desease-causing organisms. Besides the anesthetics and disinfectants, these chemicals can be grouped into antibacterials, fungicides, antivirals, and parasiticides.

ANTIBACTERIALS

The common bacterial diseases of cultured fish are: Bacterial Disease caused by myxobacteria, Bacterial Hemorrhagic Septicemia (BHS) caused by *Aeromonas liquefaciens*, Bacterial Kidney Disease (BKD) caused by *Corynebacterium salmonius*, Columnaris Disease caused by *Flexibacter columnaris*, Enteric Redmouth Disease (ERM) caused by *Yersinia ruckeri*, Furunculosis caused by *Aeromonas salmonicida*, Vibriosis caused by *Vibrio anguillarum*, and Pseudomonad Septicemia caused by *Pseudomonas*. Tables 1 and 2 show the chemicals and the bacterial diseases, and the bacterial diseases and the chemicals, respectively.

Table 1. Chemicals Used in Controlling Bacterial Fish Diseases.

Chemical	Disease in Fish
1. Chloramphenicol	Bacterial infections, especially by *Aeromonas liquefaciens* and *pseudomonas*
2. Copper sulfate	Columnaris
3. Erythromycin thiocynate (Gallimycin-50)	Bacterial Kidney Disease
4. Furacin^R	Bacteremia, Columnaris
5. Furance^R	Bacteremia, Bacterial Gill, Columnaris
6. Furazolidone	Furunculosis, Enteric Redmouth, Vibriosis
7. Hyamine 3500	Bacterial Gill Disease
8. Potassium permanganate	Bacterial Gill Disease, Columnaris
9. Roccal	Bacterial Gill Disease
10. Sulfamethazine	Vibriosis
11. Sulfamerazine	Vibriosis
12. Terramycin^R	Furunculosis, Enteric Redmouth, Vibriosis

Table 2. Bacterial Fish Diseases and Chemicals Used in Controlling Them.

Disease	Chemicals
1. Bacterial Gill	Furanace, Roccal, Potassium permanganate, Hyamin 3500
2. Bacterial Hemorrhagic Septicemia	Chloramphenicol
3. Bacterial Kidney Disease	Erythromycin thiocynate (Gallimycin-50)
4. Columnaris	Copper sulfate, Furacin^R, Furanace^R, Potassium permanganate
5. Enteric Redmouth	Terramycin, Furazolidone
6. Furunculosis	Terramycin, Furazolidone
7. Vibriosis	Sulfamethazine, Sulfamerazine
8. Pseudomond Septicemia	Chloramphenicol

FUNGICIDES

Malachite Green (anhyarodi [p-dimethylamino] triphenylmethanol salt), Roccal, and Hyamine have been used against *Saprolegnia*, the most common fungus of cultured fishes. Malachite Green is the most widely used chemical in this category. Treatment concentration varies from 0.1 ppm to 60 ppm depending on the species of fish treated, the system, and the method of treatment.

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Any fish for human or animal consumption should be treated with only those chemicals and drugs approved by the Food and Drug Administration.

It is advised that a small sample test at full concentration be run before treating the whole group of fish with any chemical.

ANTIVIRALS

There are no effective drugs or chemicals against the viral diseases of fishes. Infectious Pancreatic Necrosis (IPN), Infectious Hemopoietic Necrosis (IHN), and Viral Hemorrhagic Septicemia (VHS) are the chief viral diseases of fishes. These diseases are thought to be transmitted through the eggs and, hence, disinfection of eggs is suggested as a control measure. The term antivirals in Figure 1 is used in this context. The chemicals used in disinfecting the eggs are: Wescodyne, Betadine, Bridine, and Malachite Green.

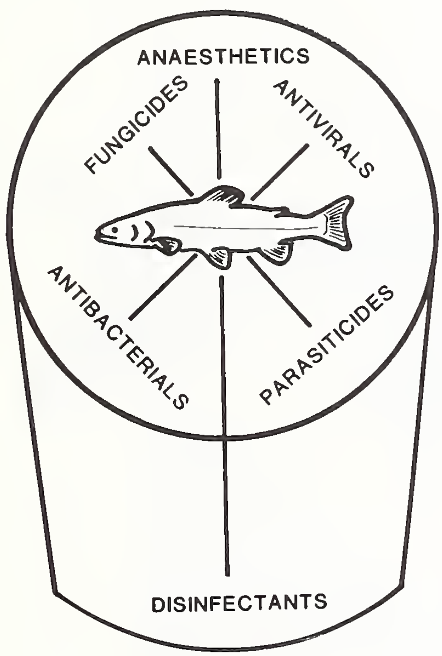

Figure 1. Major Groups of Chemicals Used in Aquaculture (*Courtesy, Author*)

PARASITICIDES

Parasitic diseases in fish are caused by both protozoans and metazoans. Among the protozoans, Ich (*Ichthyophthirius multifiliis*) and Costia are the important parasites. Both of these can be effectively controlled by a combination treatment of Formalin plus Malachite Green. Glacial acetic acid (1:500; 30 seconds dip) has been used to control costiasis.

Among the internal protozoans, Hexamita, seen in association with "pinheads," is now considered by many fish culturists as not causing any problem. Epsom salt (Magnesium sulfate) added (3%) to the feed is the usual treatment. The "pinheads" with Hexamita do not feed and it is illogical to think that the nonfeeding fish will be cured of Costia by adding a medication to the feed. Furazolidone has been recommended for coccidiosis in fish.

Many of the metazoan ectoparasites are treated with a variety of chemicals. These are acetic acid, copper sulfate, formalin, combination of formalin and Malachite Green, potassium permanganate, and salt. Salt (NaCl) has been widely used in freshwater aquaculture against bacterial and parasitic diseases. Copper sulfate should not be used in soft water. This chemical, which is also used as a disinfectant and an algicide for ponds, has been replaced by a less toxic copper oxychloride.

Di-n-butyl tin oxide is the chemical used against the intestinal helminths (flukes and tapeworms) of fishes. The chemical is added to the feed using corn oil as a binder.

Masoten^R is used against leeches. This is also used in controlling fish lice (*Argulus*) and anchor worm (*Lernaea*).

DISINFECTANTS

Disinfectants commonly used in aquaculture are: Formalin, Hyamin 3500, Purina 4X, and Roccal. Calcium Hypochlorite is a general pond disinfectant.

ANESTHETICS

Anesthetics are mainly used in aquacultural research. These chemicals are also used for safe handling of larger fish in hatcheries. Chloral hydrate, methylpentynol, MS 222 (Tricaine Methane Sulfonate), and Quinaldine are the common fish anesthetics. MS 222 is the most widely used anesthetic agent. The range of dosage is 0.5-1.0 g/gal. Fresh solution is recommended.

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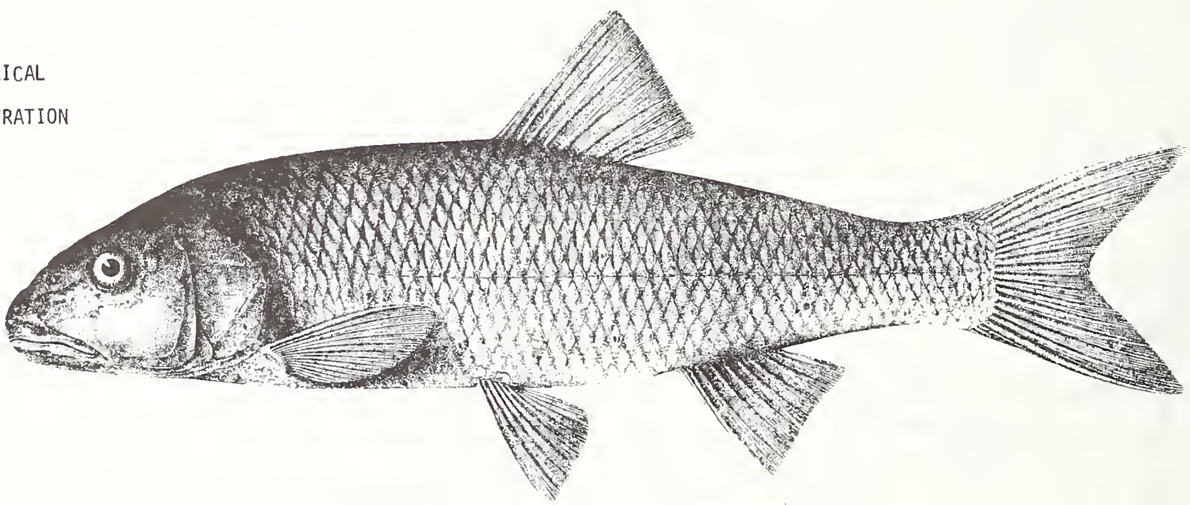

("Chilonemus Catarrhactus" as found in Six Species of North American Fresh-Water Fishes, *1889; Courtesy, National Agricultural Library)*

tions by 11,480 acres--71 percent of the planned expansion in the entire 10-state area.[2] Currently, therefore, there is every reason to believe that Mississippi catfish producers will continue to expand production capacity.

AN OVERVIEW OF THE CATFISH FARMING INDUSTRY IN MISSISSIPPI

By

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INTRODUCTION

Aquaculture, the controlled cultivation and harvest of aquatic animals and plants, evidently had its origin far back in antiquity for, as early as 475 B.C., a Chinese scholar, Fau Li, had prepared a treatise on the subject.[1] Commercial production of catfish, a branch of aquaculture, is believed to have had its beginning in 1965 with the construction, in the Delta of Mississippi, of a pond specifically for catfish production. From that meager beginning the Delta has, in 15 years, become known as the "Catfish Capital of the World" and is the focal point of a multi-million-dollar in-state industry that has approximately 33,000 acres of ponds devoted to the production of the food fish.

DEVELOPMENT OF THE INDUSTRY IN MISSISSIPPI

Apparently, Delta farmers were, in the main, not at first highly optimistic about the profit potential of the new enterprise. By the end of 1966, only a few of them had established ponds. Soon, however, the foresight, initiative, and perseverance (and, primarily, the favorable profit situation) of those early entrepreneurs led to an explosive expansion of production and the establishment of a new industry in the state.

Official data for the period are not available but it is estimated that, by 1970, the industry in Mississippi had grown to include some 15,000 acres. And, by 1973, there were an estimated 22,000 acres in food-size fish production and an additional 2,700 acres in catfish fingerlings.

Acreage devoted to catfish production in the state has already outstripped that of several crops and the enterprise is fast earning a progressively prominent place in Mississippi agriculture. A recent USDA Crop Reporting Board survey of catfish producers on farms revealed that, nationally, 56,200 water surface acres are currently devoted to production of the fish and that 32,620 of those acres are in Mississippi. Survey respondents in the 10 states expressed intentions to expand operations in 1981 by 16,100 acres. Mississippi producers reported intentions to expand opera-

GROWTH IN PRODUCTION

Farm raised catfish was a market success from the outset. Apparently, many consumers who had never eaten farm raised

Aerial view of catfish production ponds (Courtesy, The Authors)

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catfish found it much to their liking. As the product became more readily accessible on the market, sales skyrocketed. Farmer response to the tremendous expansion in quantity demanded has been substantial, as exhibited by steady increases in production. The magnitude of these changes is reflected in historical data on liveweight poundage delivered for processing. Such deliveries totaled 3.2 million pounds nationally in 1969, 40.6 million in 1979--an almost twelve-fold increase in a decade (see Table 1). In the first seven months of this year Mississippi producers sold 27.7 million pounds of food-size catfish.[3]

Substantial increases over time in the supply of a commodity evince attractive profit margins associated with the production of the commodity. The weighted average prices paid to producers at plant site in 1977, 1978, and 1979 were $. $.46,[4] $.55,[5] and $.62[6] per pound, respectively. Indications are that the 1980 weighted average price will likely be in the $.65 to $.68 range. A 1980 cost estimate developed by Waldrop and Smith ranged from $.46 to $.54 per pound, depending on farm size.[7] A comparison of cost estimates with current price levels suggests that the explosive growth rate in catfish production, particularly in Mississippi, can be mainly attributed to the relatively high profit margins being received by producers.

Other factors contributing to the rapid expansion of production in Mississippi include the general topography of the land (particularly in the Delta), the availability of water, a favorable climate, and the ease with which producers are able to fit labor and capital requirements in with ongoing farm enterprises. These factors are largely responsible for the rate of expansion in production being so much greater in Mississippi than in other states, and for the fact that most of the in-state growth has occurred in the Delta region of the state. Catfish have had a greater economic impact on that region than elsewhere because the heaviest concentration not only of production but also of processing and feed manufacturing is located there.

TABLE 1

Year	Pounds Delivered[a] for Processing	% Change
1969	3,201,000	--
1970	5,741,000	79
1971	11,257,000	96
1972	18,332,000	63
1973	19,731,000	8
1974	16,944,000	-14
1975	16,140,000	-5
1976	18,978,000	18
1977	22,125,000	17
1978	30,179,000	36
1979	40,636,000	35

[a] As reported by major processors operating in cooperation with the National Marine Fisheries Service.

GROWTH IN PROCESSING CAPACITY

The catfish processing industry has also undergone expansion commensurate with that of production. In 1970, 15 catfish processing plants reported their estimated capacity to be approximately 21.3 million pounds[8] (live weight) of catfish per year. Preliminary data taken from unpublished research by the Department of Agricultural Economics at Mississippi State University indicate that the estimated processing capacity is now 84.7 million pounds (live weight) of catfish per year. Eighty-five percent of this capacity is located in the Delta of Mississippi. In addition, at least one new processing plant is expected to begin processing in the Delta region of Mississippi in 1981. That will add 30.6 million pounds (live weight) to the catfish processing capacity located in Mississippi. These data also indicate that only four companies, operating seven plants, processed

99 percent of the total volume processed in 1979.[9]

CATFISH MARKETING

Indications are that commercially processed catfish are being marketed over a relatively wide geographic area (see Figure 1). In 1979 the most common form of catfish marketed by processors was fresh (ice packed) dressed catfish. Approximately 60 percent of all processed catfish was sold by processors in the fresh (ice packed) form while the remaining 40 percent was sold frozen. The major market outlets for processed catfish are restaurants specializing in catfish, retail grocery stores and fish markets, and nonspecialty restaurants, hotels, and other establishments serviced by food service distributors. Approximately 60 percent of the catfish sold by commercial processors in 1979 was sold through food brokers.[10]

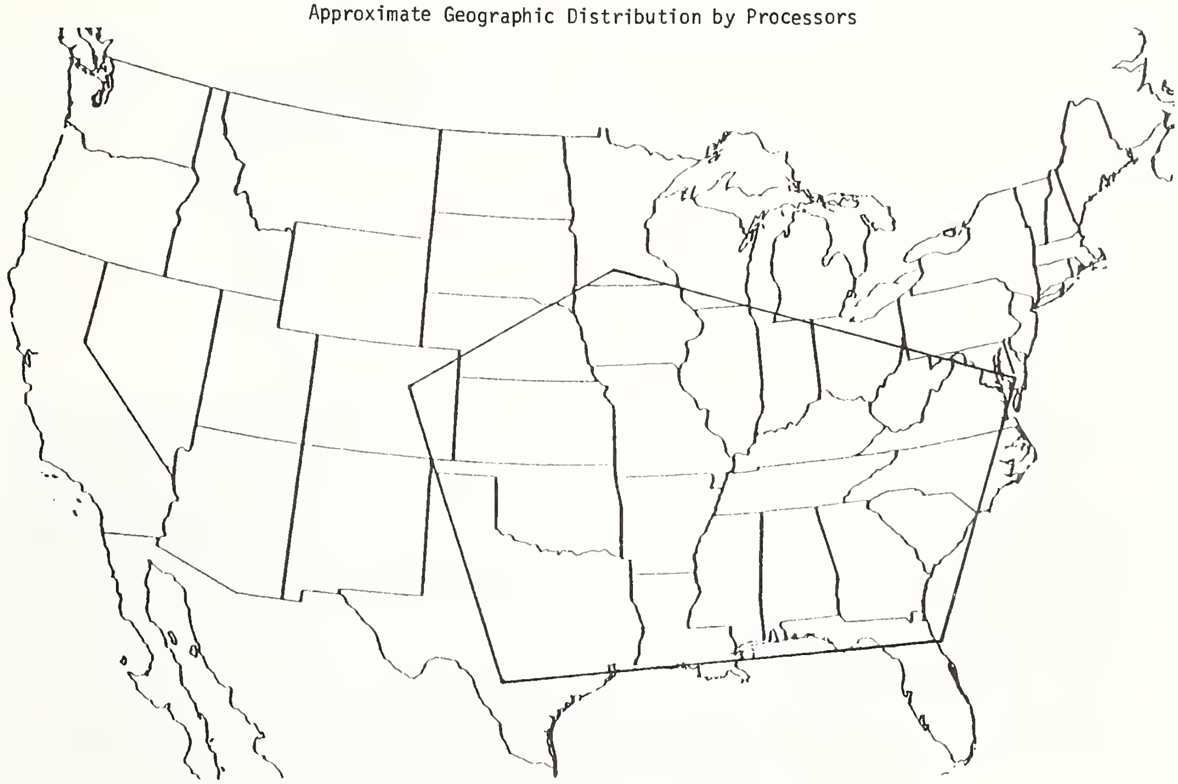
AGENCY SUPPORT

The increasing importance of the catfish industry has drawn the attention of potential entrants and various lending institutions. This interest has led to the initiation of several research projects in the major areas of production and marketing within the catfish industry.

Lending institutions such as Federal Land Bank, Production Credit Association, Farmers' Home Administration, commercial banks, and insurance companies have expressed sincere interest in the catfish for food industry. Their support and interest have enhanced the growth in production, processing, and continuing research. State, Federal, and private agencies have also supported the industry through product promotion, market development, chemical and feed regulation, and funding for continuing vital research.

FIGURE 1

Approximate Geographic Distribution by Processors



RESEARCH

Under the direction of the Mississippi Agricultural and Forestry Experiment Stations and the Mississippi Cooperative Extension Service, research and education in support of catfish production, processing, and marketing is ongoing to give guidance to the participants of this dynamic agricultural enterprise. The Mississippi Agricultural and Forestry Experiment Station has initiated research to solve pertinent problems in such important areas as water quality, genetics, stocking rates, least cost rations, growth rates, protein digestibility, and the economics of producing, processing, and marketing catfish.

Results from research in Mississippi and other states are systematically distributed by the Mississippi Cooperative Extension Service through educational workshops and consultations with new and experienced farmer-producers and processors at the local level. Publications including such topics as production economics, disease and parasite control, and weed control recommendations are also made avail-

able to anyone interested in the catfish industry.

Future research will concentrate on production economics, disease problems, genetics, nutritional requirements, market structure development, economics of processing, and other problem areas from all segments of the commercial catfish industry.

Grateful appreciation is expressed for the assistance of Mr. Dow Welch, Agricultural Economist (retired), Mississippi State University, for his efforts in the composition of this article.

Approximately 600 pounds of catfish being harvested from pond (Courtesy, The Authors)

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10. *Ibid.*

Fresh processed fish ready for packaging and distribution
(Courtesy, The Authors)

SELECTED LIST OF PUBLICATIONS

RELATING TO AQUACULTURE

AND THE AMERICAN FOOD SUPPLY

Today there is a growing concern for and interest in the field of aquaculture particularly as it relates to the American food supply. The following list of publications has been selected from an AGRICOLA (AGRICultural On-Line Access) search of *File 110* and *File 10* conducted by Charles Bebee, Head of the National Agricultural Library's Automated Search Service. AGRICOLA consists of indexes to world-wide journal and monographic literature and U.S. Government reports on general agriculture, food and nutrition, agricultural economics, and many related scientific and sociological subject fields. Over 1,400,000 records are included in the file which covers literature published since 1970. For further search information on this and many other agriculturally related subjects, contact Charles Bebee, Room 111, National Agricultural Library, Beltsville, Maryland 20705. When available, the NAL call number is provided in parentheses at the end of each citation.

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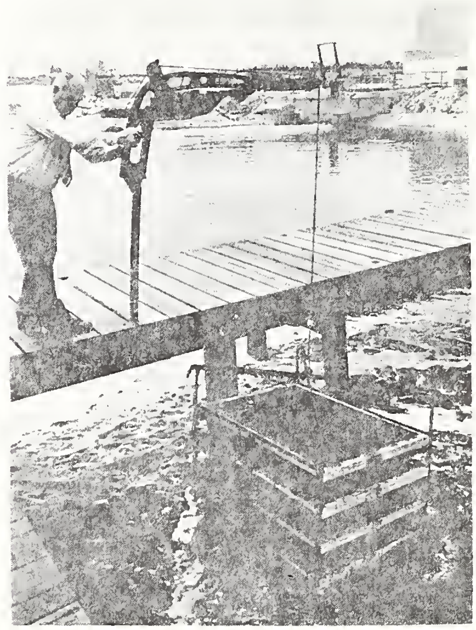

Oyster tray culture in heated pond, Long Island Oyster Farms. (Courtesy, New York State Department of Commerce)

NEW ACQUISITIONS

Aquaculture has always been an important part of the National Agricultural Library's collection. Materials on fish were acquired because of varied reasons: fish are a source of food and a type of wildlife; fish-farming is an aspect of agriculture; fishing is a sport; fisheries are food processing plants. Since the passage of the National Aquaculture Acts and the new emphasis on aquaculture in agriculture, the National Agricultural Library has increased the number of aquacultural-related titles in the collection and currently acquires aquacultural materials on a broad scope.

The National Agricultural Library has been engaged in several activities related to aquaculture: membership in the Joint Subcommittee on Aquaculture--Panel on Translations (a source of more than fifty translations of aquaculture articles a year) and participation in the SEA Aquaculture Program. Researchers will note many more citations for aquaculture in the AGRICOLA data base as more aquaculture materials are acquired, catalogued, and indexed. In cooperation with AGRIS, the National Agricultural Library has introduced a new subject category specifically related to aquaculture.

The following list is a sample of the materials in the Library's collection related to aquaculture. The NAL call number is provided with the title (if available). Persons having questions or suggestions concerning this listing should contact Beth Whiting, Cataloging Section, Room 110, NAL, Beltsville, Maryland 20705.

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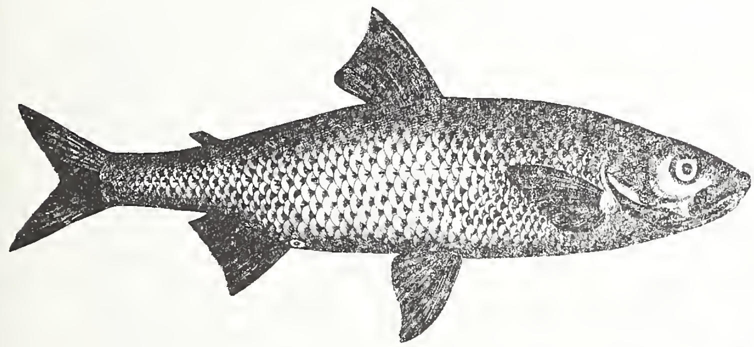
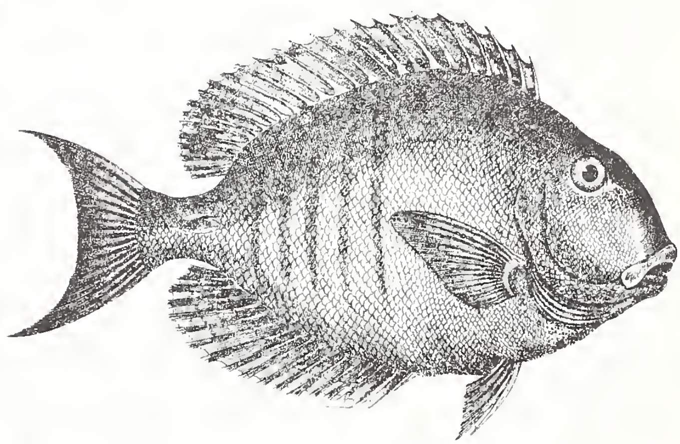
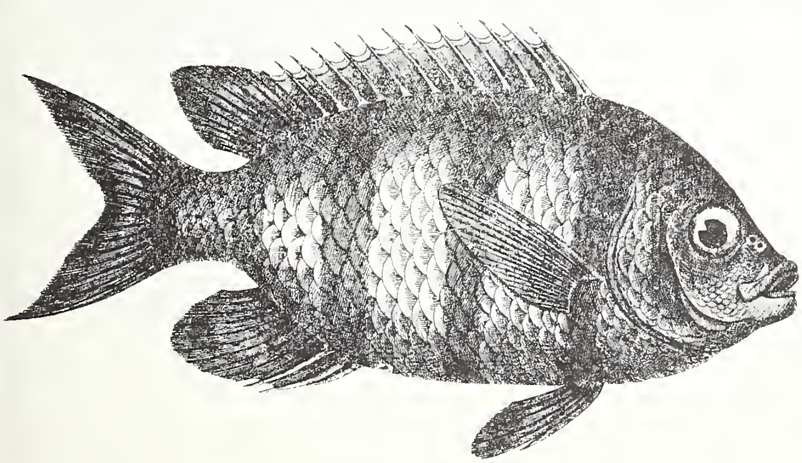


HISTORICAL

ILLUSTRATIONS





("La Marene," top left, "Le Chirurgien," middle, "Le Jagague," bottom left, as found in Bonnaterre's Tableau Encyclopédique et Méthodique . . . Ichthyologie, *1788; Courtesy, National Agricultural Library, Rare Book Collection)*

NEWS NOTE

NAL VIDEOTAPE AVAILABLE: "THE INFORMATION CYCLE"

There is available a 20-minute, color, videotape describing NAL's information systems and services, and the processes involved in transferring information from scientists to educators.

The videotape, called "The Information Cycle," presents and describes the Agriculture Literature (AGRICOLA) and Current Research Information (CRIS) data bases, the Current Awareness Literature Service (CALS), and Food and Nutrition Information Services (FNIC), and the Document Delivery Systems of the National Agricultural Library.

Copies of the tape, in 3/4" cassette, are available for loan from: Educational Resources Division, Training and Education Branch, USDA, Beltsville, Maryland 20705; Attention: David Hoyt.

ALA SATELLITE BROADCAST

The National Agricultural Library was a receiving station for a special program on marketing from the American Library Association's Midwinter Meeting satellite broadcast on January 26, 1982, from 11:00 a.m.-1:00 p.m. The broadcast was live from Denver via SATCOM I. NAL was one of 40 regional receiving centers located around the country. Invitations were extended to the Federal and Metro library community to view the broadcast in the NAL building. The theme of the broadcast program was "Marketing: A Key to Surviving and Thriving." Speakers included the following: Philip Kotler, Professor of Marketing, Northwestern University; Daniel Carrol, President of Hoover Universal, and Danforth Sawyer, Public Printer of the United States. The moderator was Shirley Echelman, Executive Director of the Association of Research Libraries.

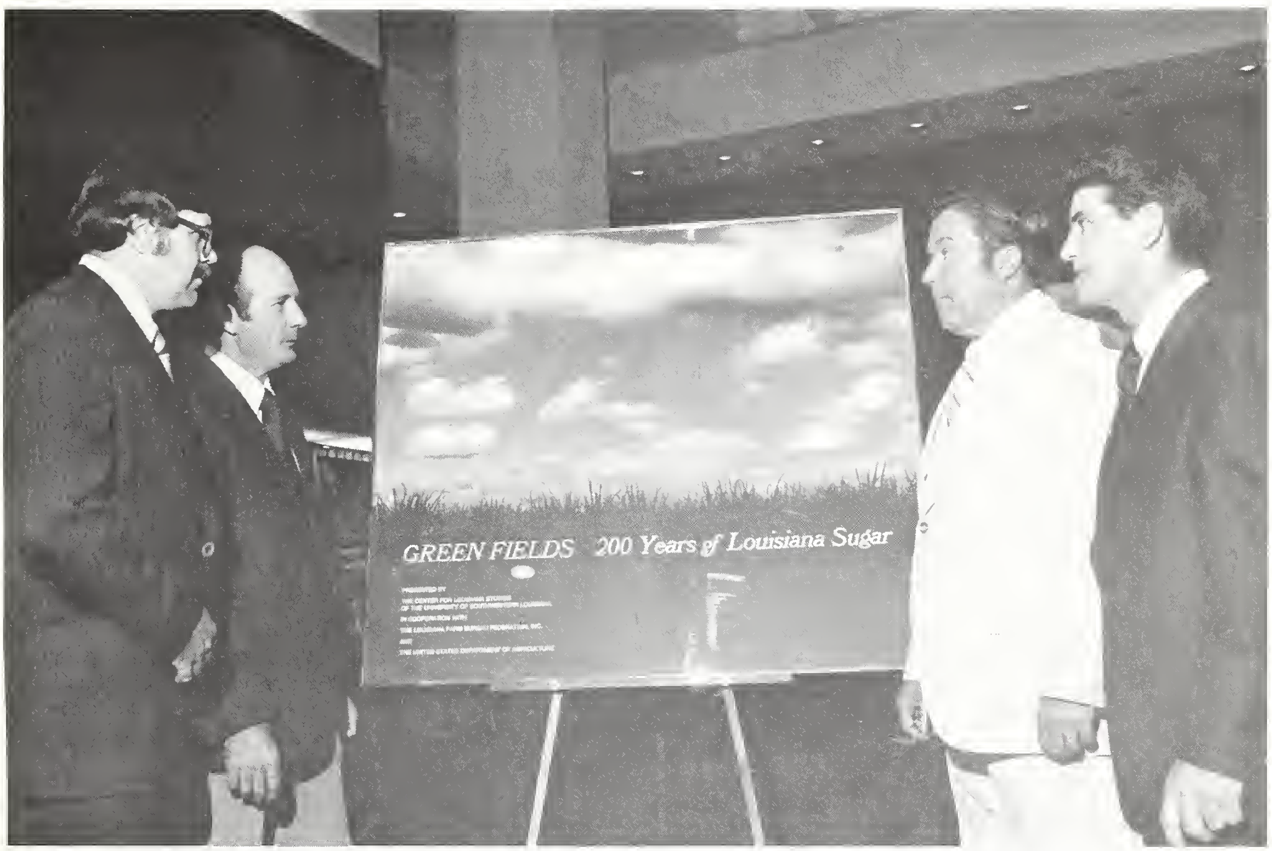
This satellite broadcast was jointly sponsored and funded by the Associates NAL, Inc., the Federal Library Committee, and the Federal Librarians Round Table.

A VANISHED LANDMARK

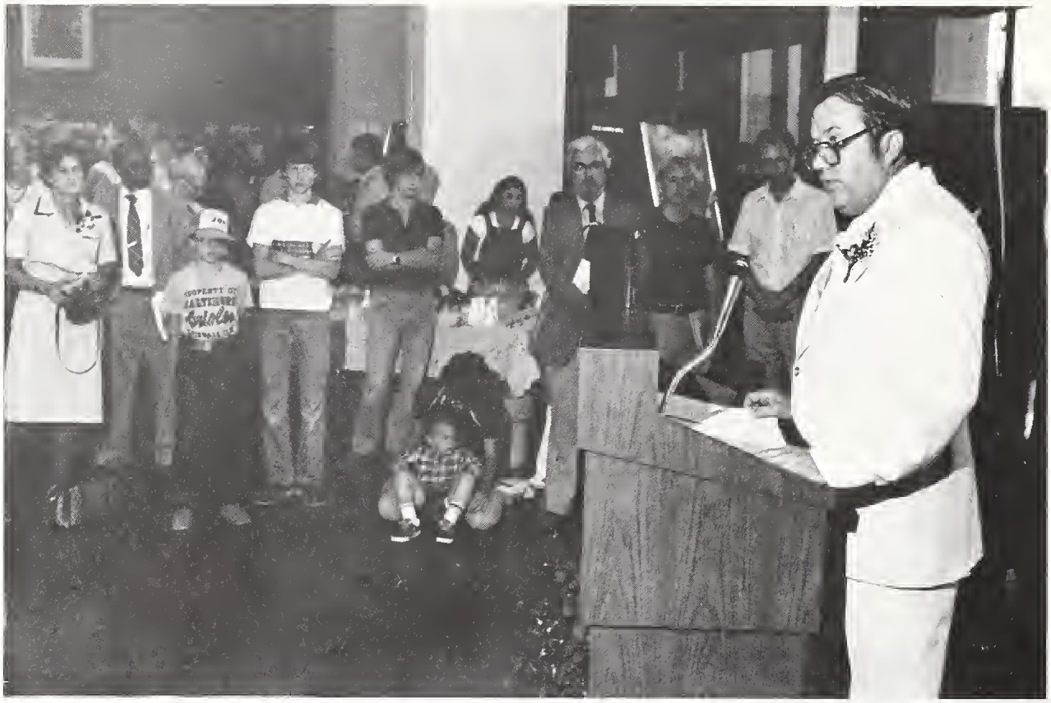
Do you have information regarding this landmark? The caption or the photograph reads as follows: "The old redwood tree, long a landmark on Department grounds;" the credit line reads "USDA Photo." If you have any comments or recollections, please send them to Dr. Alan Fusonie, Historical and Preservation Program Specialist, Room 301, National Agricultural Library, Beltsville, Maryland 20705.

GREEN FIELDS: TWO HUNDRED YEARS OF LOUISIANA SUGAR: A PICTORIAL HISTORY

This exhibit was presented by the Center for Louisiana Studies of the University of Southwestern Louisiana in cooperation with the Louisiana Farm Bureau Federation, Inc. and the U.S. Department of Agriculturé (USDA), Science and Education Administration (SEA), Technical Information Systems. The dedication ceremony was held at the National Agricultural Library, Beltsville, Maryland, on Thursday, July 9, 1981.



Master of Ceremonies, Alan Fusonie (far left), Historical and Preservation Program Specialist, National Agricultural Library, USDA, views opening panel of the Green Fields exhibit with (from left to right) Jackie Theriot, Vice Chairman of the Sugar Cane Committee, Louisiana Farm Bureau Federation, Inc.; Glen Conrad, Director, Center for Louisiana Studies of the University of Southwestern Louisiana, and Sam W. Cosper, Academic Vice-President of the University of Southwestern Louisiana. (Courtesy, U.S. Department of Agriculture).



Glen Conrad, Director of the Center for Louisiana Studies of the University of Southwestern Louisiana delivered a moving keynote address highlighting how the exhibit portrays the history, technology, and architecture of 200 years of sugar in Louisiana. (Courtesy, U.S. Department of Agriculture).

The Michael Doucet Dit Beausoleil Trio. From left to right, Michael Doucet, fiddler and singer, is accompanied by Errol Verret, on accordian, and David Doucet, on guitar. A lively concert of authentic Louisiana Cajun music added a festive air to the dedication ceremony. The group takes its name from Beausoleil Broussard, leader of a small resistance during the Grand Derangement when the Acadians were exiled from their native land (now Nova Scotia) by the British in 1755. (Courtesy, U.S. Department of Agriculture).

NAL RECEIVES A RARE PUBLICATION

A very rare four volume set entitled Album of Japanese Flowering Cherry Tree Drawings *was recently donated to the National Agricultural Library by Kanematsu Funatsu. These drawings were compiled by Funatsu's grandfather, Seisaku Funatsu, to depict the original cherry selections planted in the 1800's in the Kohoku area of the Arakawa River.*

The following translation of the foreword to these drawings explains their value:

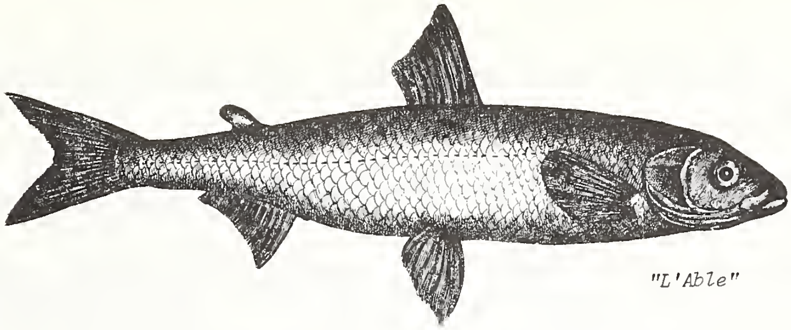
> *KOHOKU O-FU SHO (foreword to Kohoku Sakura Pictorials)*
>
> *Beautiful drawings compiled as albums here are the results of Mr. Seisaku Kohoku-tei (Kohoku Embankment). He has commissioned a painter to make pictorial recordings of SAKURA flowers in this area over the years which finally resulted into those beautiful drawings. Kohoku SAKURA are some of the most outstanding SAKURA of Japan.*
>
> *Gentle Mr. Funatsu loved SAKURA and actively sponsored and protected those SAKURA while making them widely known not only throughout Japan but overseas as well. Seeing these albums attest to his efforts. We are totally indebted to him for his ceaseless support of Kohoku SAKURA and greatest appreciation is expressed here.*

During recent research travel in Japan, Roland Jefferson, botanist with the U.S. National Arboretum, contacted Kanematsu Funatsu and was instrumental in expediting the donation of this rare gift.

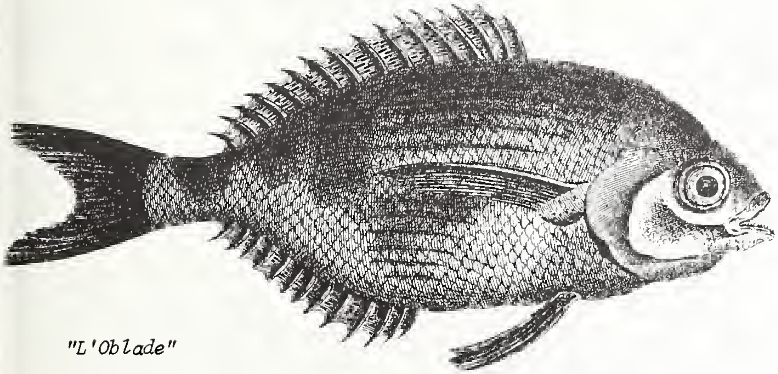
Left to right: H. Marc Cathey, Director, U.S. National Arboretum; Richard A. Farley, Acting Director, National Agricultural Library, and Roland Jefferson, botanist, examine one of the rare albums. (Courtesy, U.S. Department of Agriculture).

PRESERVING THE WRITTEN RECORD

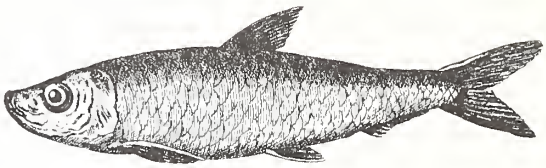
During a visit to the National Agricultural Library, Dr. Henry Marc Cathey, Director of the U.S. National Arboretum, examines rare and recently restored hand-written record books of William Saunders (1822-1900), horticulturist, landscape gardener, and first federal superintendent of the experimental gardens of the U.S. Department of Agriculture. (Courtesy, U.S. Department of Agriculture).



"L'Able"



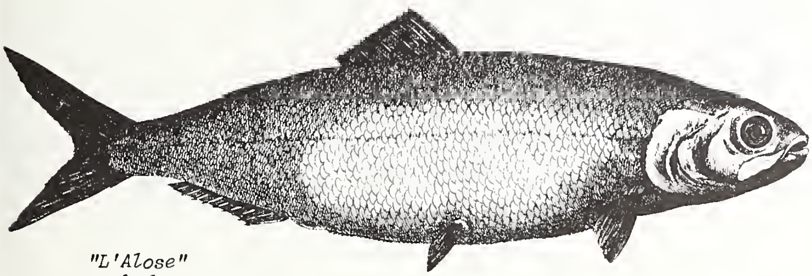
"L'Oblade"



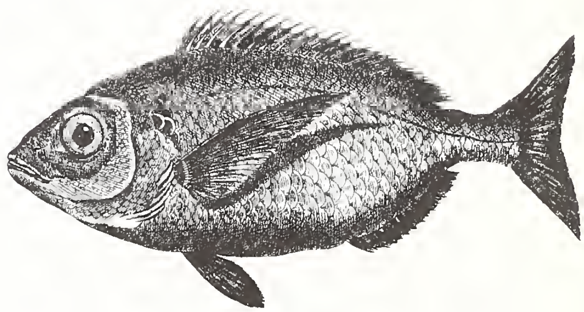
"La Sardine"

HISTORICAL ILLUSTRATIONS

(From Bonnaterre's Tableau Encyclopédique et Méthodique . . . Ichthyologie, *1788; Courtesy, National Agricultural Library, Rare Book Collection)*



"L'Alose"
[*shad*]



"La Dorade"

"L'Anchois"
[*anchovy*]

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